Enhancing Joint Capabilities in Theater Ammunition Management

John F. Schank, James P. Stucker,
Gerald Sumner, Michael G. Mattock

RAND | NATIONAL DEFENSE RESEARCH INSTITUTE

The research described in this report was sponsored by the Joint Staff. The research was conducted in RAND's National Defense Research Institute, a federally funded research and development center supported by the Office of the Secretary of Defense and the Joint Staff, Contract No. MDA903-85-C-0030.

Library of Congress Cataloging in Publication Data

Enhancing joint capabilities in theater ammunition management / John F. Schank ... [et al.].
p. cm.
"Prepared for the Joint Staff."
Includes bibliographical references.
"R-3789-JS."
ISBN 0-8330-1027-1
1. United States – Armed Forces—Supplies and stores. 2. Ammunition. 3. Unified operations (Military science). 4. United States—Armed Forces—Management. I. Schank, J. II. United States. Joint Chiefs of Staff. III. RAND Corporation.
UC263.E54 1990
355.8'25—dc20

89-70195
CIP

The RAND Publication Series: The Report is the principal publication documenting and transmitting RAND's major research findings and final research results. The RAND Note reports other outputs of sponsored research for general distribution. Publications of RAND do not necessarily reflect the opinions or policies of the sponsors of RAND research.

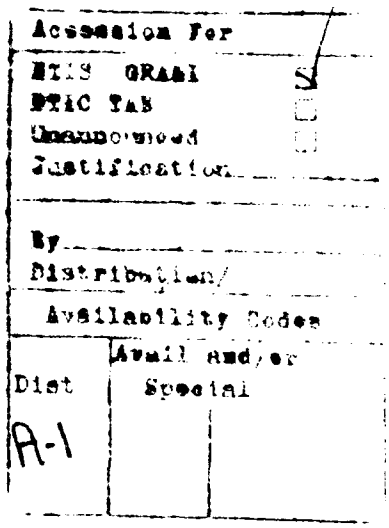
Published 1991 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

R-3789-JS

Enhancing Joint Capabilities in Theater Ammunition Management

John F. Schank, James P. Stucker,
Gerald Sumner, Michael G. Mattock

Prepared for the
Joint Staff



RAND

PREFACE

Within a theater of operations, a set of logistic resources and functions span multiple services. These logistic assets are either jointly used, jointly maintained, or jointly delivered. The uncertain and dynamic environment of wartime, coupled with the limited availability of logistic resources, will inevitably result in conflicts for these joint resources—conflicts that can only be resolved by the theater unified commander-in-chief (CINC). Flexible and responsive management systems will be necessary to assist in allocating these resources in concert with the CINC's operational goals and priorities.

Working from the above premise, RAND has undertaken a long-term project entitled "Achieving Maximum Effectiveness from Available Joint/Combined Logistic Resources." The project's first task reviewed service and Defense Logistics Agency logistic structures and systems and surveyed the needs and opportunities for improving the joint command and control of three categories of logistic resources in wartime: bulk fuels, conventional ammunition, and spare parts. The outcome of the first research phase was the identification of the CINCs' logistic staffs' broad roles and responsibilities in wartime and the specification of the general types of information and models necessary to fulfill those roles. That research is documented in S. C. Moore, J. P. Stucker, and J. F. Schank, *Wartime Roles and Capabilities for the Unified Logistic Staffs*, The RAND Corporation, R-3716-JCS, 1990.

This report documents the results of a second task, which focused on identifying improved, practical mechanisms for the CINC/Logistics Directorate staffs to use in monitoring and assessing theater capabilities with respect to *conventional ammunition* in wartime. Conventional ammunition was chosen for more detailed analysis during the second research phase because bulk fuels are currently "jointly" managed to a large degree and because improvements can be made more quickly and easily in the ammunition area than in the spare parts area.

This research was sponsored by the Joint Staff and conducted within the Acquisition and Support Policy Program of RAND's National Defense Research Institute, a federally funded research and development center for the Joint Staff and the Office of the Secretary of Defense.

This document should be of interest to logistic and operations planning staffs—especially to those concerned with ammunition resources—at the Joint Staff, unified commands, and theater components.

SUMMARY

At least partially because logistics has traditionally been considered a service function, the logistic staffs assigned to unified theater commands are typically small, with little data handling, processing, or display capabilities. However, some theater logistic duties can only be handled at the unified level. Just as the unified commander must task, coordinate, and oversee the *operations* of his component commands, so too must he (with the assistance of his logistic staff) task, coordinate, and oversee some of their *logistic* functions, especially those relating to jointly used, jointly delivered or jointly maintained resources. Each unified commander must also monitor the theater and worldwide status of certain critical items, the so-called war stoppers, regardless of which component owns or controls them.

Our research for the Logistics Directorate (J-4) of the Joint Staff focuses on adaptive, dynamic responses to wartime uncertainties. The first phase of this research developed and discussed four broad roles for the theater logistic staffs—roles that are neither feasible nor appropriate for the component staffs.[1] This report documents the findings of the second phase of our research, extending the discussion to cover the information and information-handling capabilities needed by the unified commands so they can constantly assess the theater position with regard to conventional ammunition and summarize for the commander-in-chief (CINC) how that position affects the war-fighting abilities of his forces. We focus on simple, modular capabilities designed to run quickly on personal computers.

WARTIME ROLES FOR THE UNIFIED LOGISTIC STAFF

The first phase of our research surveyed the needs and opportunities for improving the command and control of joint logistic assets in wartime and identified four broad roles for the CINC's logistic staff:

- Monitoring current and evolving theater logistic capabilities;
- Coordinating logistic support with current and planned operations;

[1]The results of task 1 of the research are documented in S. C. Moore, J. P. Stucker, and J. F. Schank, *Wartime Roles and Capabilities for the Unified Logistic Staffs*, The RAND Corporation, R-3716-JCS, 1990.

- Advising the unified commander about the supportability of proposed operations and courses of action;
- Acting as agent/advocate to nontheater logistics organizations.

We then assessed the current abilities of the CINC/J-4s to meet these four wartime roles for three types of logistic resources: bulk fuels, conventional ammunition, and spare parts. Based largely on observations at the United States Pacific Command (USPACOM) (for all three resource areas) and at the United States Central Command (USCENTCOM) (for ammunition), we found that the CINC/J-4s have relatively good capabilities for fulfilling the roles with respect to bulk fuels, that they have little capability with regard to ammunition or spare parts, and that spare parts may not, in fact, be an appropriate arena for near-term joint developments. Consequently, the second phase of our research concentrated on ammunition.

ENHANCED CAPABILITIES FOR SUPPORTING CONVENTIONAL AMMUNITION

This report describes the results of task 2 of the research, which had the objective of identifying improved practical mechanisms for the unified commands' logistic staffs to use in monitoring and assessing capabilities with respect to *conventional ammunition* in wartime. We identify the types of data, knowledge, and analytic models the CINC/J-4 needs to improve ammunition assessment and reporting capabilities in wartime, and we evaluate the potential for meeting those needs with existing capabilities and with models currently under development.

To assist the joint commander in allocating limited logistic resources in ways that maximize combat capability, his logistic staff must be able to estimate both the quantity of assets *available* within the theater and the quantity of assets that will be *required* to support current and proposed operations. And the staff must be able to estimate those availabilities and requirements not only for the *current time period*, but also for *future time frames*. They must provide the commander with estimates of the most probable values for availabilities and requirements, and they should illustrate with upper and lower confidence bounds the risk associated with their estimates.

However, the staff's functions must go beyond the estimation of asset availabilities and requirements. They must also be able to recognize supportability and sustainability problems and to identify possible solutions to those problems. To fulfill all these tasks, they must have (1) *data* on the status of assets and on planned operations, (2) *knowledge* about the joint aspects of various resources and the consumption

of those resources for planned operations, and (3) a set of *analytic tools* to manipulate the data and knowledge to provide the necessary estimates of asset availabilities and requirements.

The data, knowledge, and analytic tools must all interact to develop and present the information needed by the CINC and his staff. A representation of this interaction is depicted in Fig. S.1. We next present specific recommendations to improve the data, knowledge, and analytic tools available to the CINC and his staff. We provide more details on the data, knowledge, and tools, plus their overall interactions, in the body of the report.

Recommended Data Improvements

To fulfill its wartime roles, the unified logistic staff needs data on

- Current (or as recent as possible) ammunition inventory counts for the theater, by geographic region;
- Ammunition stocks en route to the theater, including when and where they are expected to arrive;
- Characteristics of current, planned, and proposed operations, including battle intensity, geographic region, sortie schedules, and so on;
- Types and quantities of remaining threat-oriented targets;
- Changes in ammunition storage, handling, and transportation capacities available within the theater.

Data systems currently exist that can provide the CINC/J-4 with some information about ammunition inventories in the theater. The other categories of data currently do exist, or will at other directorates on the CINC's staff and at organizations such as the United States Transportation Command and the single manager for conventional ammunition. We know of no plans, however, for making those data available to the CINC/J-4s in a format and at a level of aggregation they can handle. **We recommend that actions be taken to reexamine the critical item lists for ammunition, to define the units of measurement for reported data, and to establish formats and media for the data sent from the components to the CINCs' staffs.**

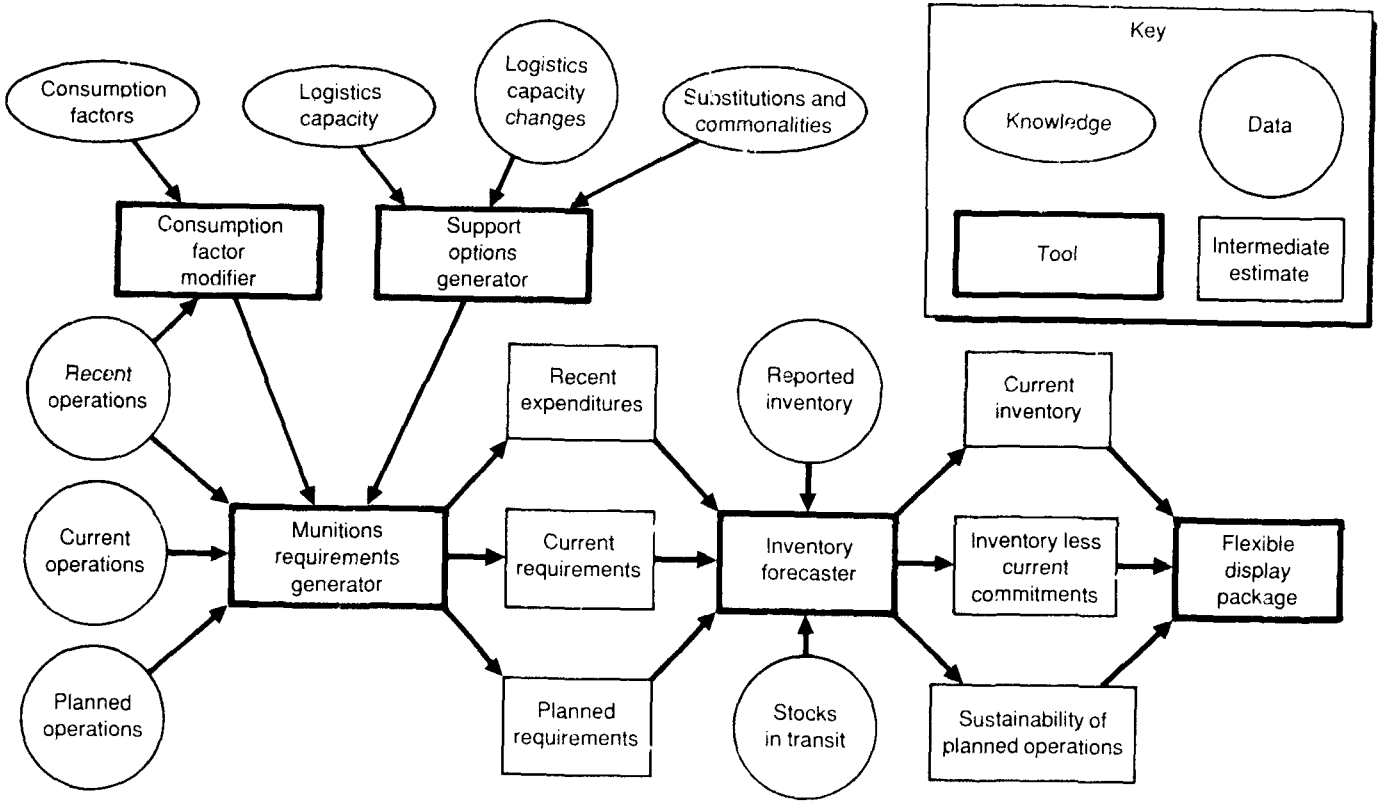


Fig. S.1—Interactions of data, knowledge, and analytic tools

Recommended Knowledge Improvements

The data items identified above must be supplemented by a knowledge base (that can be developed in peacetime) for use during wartime. The major parts of the knowledge base include

- Types of ammunition used by more than one service, including the weapon system interface requirements that allow interoperability;
- Consumption factors relating ammunition requirements to different types and intensities of operations;
- Ammunition substitutabilities and their relative effectiveness;
- Storage, handling, and transportation factors for these types of ammunition.

Fragments of these knowledge components are currently available in some theaters. **We recommend that a concentrated effort be undertaken, largely by the Joint Staff, to organize and disseminate this knowledge base.**

Recommended Analytic Tool Improvements

Finally, the data and knowledge must be augmented by analytic tools to develop and display the types of information needed by the CINC. These tools include

- A model to update ammunition consumption factors and other knowledge factors based on recent wartime experience;
- A model to forecast ammunition stock levels based on recent inventories, expected resupply, and expected consumption;
- A model to estimate ammunition requirements for various types of operations;
- A method to identify substitute ammunition or other service components that use a type of ammunition that is causing supportability problems;
- An integrated graphics package for aggregating, summarizing, and displaying ammunition availabilities and requirements.

Currently, some analytic capability exists within the logistic directorates of the operating theaters and at the Joint Staff level, and several sophisticated ammunition management systems are under development. We find no models, however, that explicitly recognize wartime uncertainties about ammunition use or availability, and none that directly address the specialized wartime concerns of the theater commands. **We recommend that such models be developed.**

Our discussions with the CINC/J-4 staffs at USPACOM and USCENTCOM revealed that they currently have only limited capabilities to assist the CINC in wartime. They will receive some data from their service components and they have developed some spreadsheet-based tools, but in general they are ill-prepared to address the range of supportability and sustainability issues likely to arise in wartime. We believe that the several easy-to-implement improvements described in this report in data, knowledge, and analytic tools could greatly increase their capabilities, expand their appreciation of wartime uncertainties, and move them substantially closer to the full range of capabilities necessary to fulfill their wartime roles without requiring large increases in staff size or funding.

ACKNOWLEDGMENTS

We received substantial help in understanding the services' overall capabilities for providing and managing logistic support to U.S. forces abroad through many individuals. Our guides, critics, and facilitators at the Joint Staff included Brig. Gen. William Halli- (United States Air Force [USAF]), Mr. Bill Boone, Col. William Smiley (USAF), COL. Karl Dahlen (United States Army), Col. Ray Linville (USAF), and Mr. Michael Brenzy.

Special thanks must go to members of the logistic staffs at the United States Pacific Command and its components' headquarters, who introduced us t many of the wartime interactions between the unified command and the individual services, and to members of the logistic staff at the United States Central Command, who provided a second perspective.

RAND colleagues Craig Moore, John Bondanella, and Bart Bennett reviewed the draft report and offered many useful suggestions to improve and clarify the presentation.

CONTENTS

FIGURES

TABLE

GLOSSARY

AMCCOM	Armament, Munitions, and Chemical Command (Army)
ARG	ammunition requirements generator (JS/J-4)
ARMS	ammunition reporting management system (USPACAF)
C2IS	command and control information system (USCENTCOM)
CAIMS	conventional ammunition integrated management system (Navy)
CAMOPAC	Central Ammunition Management Office—Pacific (Army)
CAPLOG	munitions logistics capability model (Navy)
CASES	capability assessment expert system (USPACFLT)
CAT	crisis action team
CINC	commander-in-chief
CINC/J-2	Intelligence Directorate in a unified theater command
CINC/J-3	Operations Directorate in a unified theater command
CINC/J-4	Logistics Directorate in a unified theater command
CINC/J-5	Plans and Policy Directorate in a unified theater command
CINCPACFLT	commander-in-chief Pacific Fleet
CONUS	continental United States
DMT	deployment mobility team
DOS	days of supply
FM	field manual
FMFPAC	Fleet Marine Forces, Pacific
FRESH	force requirements expert system (USPACFLT)
GUARDS	general unified ammunition reporting data system (JS/J-4)
J-2	Intelligence Directorate
J-3	Operations Directorate
J-4	Logistics Directorate
J-5	Plans and Policy Directorate
JCS	Joint Chiefs of Staff
JOC	joint operations center

JOPS	joint operation planning system
JS	Joint Staff
LOC	logistics operations center
LOE	level of effort
MAGTF I	Marine Air-Ground Task Force lift requirements and logistics planning factor model I
MTMC	Military Traffic Management Command (Army)
NNOR	nonnuclear ordnance requirements (Navy)
OPLAN	operational plan
OPT	operations planning team
OSGP	operations support group prototype (USPACFLT)
PA&E	Programs, Analysis, and Evaluation branch (USCENTCOM/J-4)
PC	personal computer
POM	program objective memorandum
SAAS	standard Army ammunition system
SMCA	single manager for conventional ammunition (Army)
SPCC	Ship Parts Control Center (Navy)
TO	threat-oriented
TPFDD	time-phased force deployment data
USAF	United States Air Force
USCENTCOM	United States Central Command
USPACAF	United States Pacific Air Forces
USPACFLT	United States Pacific Fleet
USPACOM	United States Pacific Command
USTRANSCOM	United States Transportation Command
WARS	worldwide ammunition reporting system (Army)
WESTCOM	Western Command (Army)

I. INTRODUCTION

The commander-in-chief (CINC) of a U.S. unified command develops the strategies for and oversees the development of operational plans for the employment and sustainment of the U.S. military forces in his theater or geographic area of responsibility. This requires the CINC and his staff to engage in mobilization and deployment planning and to participate in the Department of Defense's planning, programming, and budgeting system, working to ensure that adequate combat and support resources can be available in the theater quickly enough and long enough to enable implementation of current operational concepts and employment plans.

The CINC has operational command over his service components in both peacetime and wartime, but the provision of logistic support for forces—in the form of food, fuel, ammunition, transport, spare parts, repair, and so on—has historically been designated as a service responsibility. However, the CINC has "directive authority" over logistics, and in wartime this authority permits him to "authorize commanders to use all facilities and logistic resources available as necessary for the accomplishment of their operational missions."[1]

The omnipresent uncertainties of wartime make difficult predicting the quantity of logistic resources that will be necessary to support combat operations. Peacetime budget constraints complicate the logistician's problem by restricting the amount of logistic resources that will be available at the start of any war. Given this uncertainty of demand and the constrained supply, the CINCs must have flexible and responsive management systems that can identify potential sustainability and supportability problems and allocate logistic resources in concert with operational plans and objectives.

WARTIME ROLES OF THE CINC/J-4 STAFF

The first phase of our research into the wartime use of joint logistics identified needs and opportunities for improving command and control of logistic resources within a theater of operations. It centered on the roles and missions of the CINC's logistic staff—that is, the problems it must confront, the decisions it must make, and the questions it must

[1]Joint Chiefs of Staff (JCS), *The Unified Action Armed Forces (UNAAF)*, JCS Publication 2, December 1986.

answer.[2] Task 1's major output was an initial definition of wartime roles and responsibilities of the CINC/Logistics Directorate (J-4) staff.

Currently, the wartime roles and responsibilities of the joint logistic staffs are not specified consistently and systematically in official publications of the joint community. Nevertheless, a general recognition that several types of duties are clearly in the province of the unified command appears to exist. Just as the unified commander must task, coordinate, and oversee the operations of his component commands, so too must he (with the assistance of his logistic staff) task, coordinate, and oversee at least some of their logistic functions, especially those relating to jointly used, jointly delivered, or jointly maintained resources. Each unified commander must also continually monitor the theater and worldwide status of certain *critical items,* the so-called war stoppers, regardless of which component owns or controls them.

The United Action Armed Forces[3] distinguishes unified commands' and components' responsibilities generically within individual functional areas—for example, engineering, supply, and medical—without establishing the overriding responsibilities of the CINC/J-4 or the information necessary to enable fulfillment of those responsibilities. Based on our interviews with operations and logistic staffs at both the unified and component levels, however, we discerned four relatively distinct roles the CINC/J-4 staff should provide in wartime. The roles are:

1. **Monitor current and evolving theater logistic capabilities.** That is, collect, consolidate, and interpret data about current and upcoming logistic assets in the theater, relating those data to current and planned operations.
2. **Coordinate logistic support with current and planned operations.** This includes assigning agents and priorities for moving, storing, and using joint assets, as well as for maintaining the balance of those assets commensurate with upcoming and probable operations.
3. **Advise the CINC about the supportability of proposed operations and courses of action.** This includes conducting preliminary macro assessments of course-of-action supportability *before* consulting the components as well as evaluating the components' judgments and predictions after they are received.

---

[2]The results of task 1 of the research are documented in S. C. Moore, J. P. Stucker, and J. F. Schank, *Wartime Roles and Capabilities for the Unified Logistic Staffs,* The RAND Corporation, R-3716-JCS, 1990.

[3]JCS, *UNAAF.*

4. **Act as the CINC's agent/advocate with logistic organizations outside the theater.** This includes interacting with the Joint Staff (JS)/J-4, Defense Logistics Agency, United States Transportation Command (USTRANSCOM), and so on, and reporting theater logistic status, requesting resources beyond those allocated, overseeing priorities conveyed to supporting organizations, and coordinating support interactions with theater allies.

We concluded task 1 by defining the general types of information and models needed to perform the four roles in wartime and by assessing the current capabilities of the CINC/J-4s for three types of logistic resources: bulk fuels, conventional ammunition, and spare parts. Based largely on observations at the United States Pacific Command (USPACOM) (for all three resource areas) and at the United States Central Command (USCENTCOM) (for ammunition), we found that the CINC/J-4s have relatively good capabilities for fulfilling the roles with respect to bulk fuels,[4] but they fall significantly short in the areas of ammunition and spare parts.

TASK 2 RESEARCH OBJECTIVES

Because we judged that improvements could be made more quickly and easily in the ammunition area and because ammunition is more of a "joint" asset than spare parts, we focused the next phase of our research on conventional ammunition. Working from the broad roles identified during task 1, we sought to identify improved, practical mechanisms for the CINC/J-4 staffs to use in monitoring and assessing capabilities with respect to *conventional ammunition*[5] in wartime. These mechanisms should provide the capability to measure the quantity of selected ammunition *available* within the theater and the quantity of ammunition *required* to support operations. The availabilities and requirements must be measured not only for the *current time period*, but also estimated for *future time frames*.

[4]The ability to perform the four hypothesized roles was judged fair to good for bulk fuels because relatively few major types of fuel exist, they are handled separately from other commodities, and the wholesale portions of the fuel supply system are managed jointly. The major weakness in theater CINCs' fuel-monitoring capabilities is the inability to estimate the fuels usage associated with different potential operations.

[5]Munitions are "conventional" if they are not nuclear, biological, or chemical weapons. Although in the strictest sense ammunition is a subset of munitions, we use the two terms interchangeably throughout the text. We do not intentionally exclude any subset of conventional ammunition. As we explain further in Sec. III, our focus is on class V items that are used by more than one service or whose supply within the theater is believed to be below the quantity necessary to support operational objects.

To fully support the theater commander, however, the functions of the CINC/J-4 staffs should go beyond the measurement of ammunition availabilities and requirements. They should also be able to recognize supportability and sustainability problems and identify solutions to those problems.

PLAN OF THIS DOCUMENT

This report describes the results of task 2. It defines the data, knowledge, and analytic tools required by the CINC/J-4 staffs in wartime and compares those requirements with the capabilities that currently exist or are under development. Based on those requirements and capabilities, we make several recommendations for enhanced data, knowledge, and models that would improve the CINC/J-4 staffs' ability to assess the ammunition supportability of current and planned operations.

The next section defines the meaning of the CINC/J-4s' wartime roles in the area of conventional ammunition and discusses some problems associated with performing those roles. The following three sections describe, respectively, the data, knowledge, and analytic tools necessary to fulfill the roles. Section V also describes several models currently under development and how those models will (and won't) help to meet the data and modeling requirements. Section VI summarizes the recommendations for filling the gaps between what exists and what is needed. Finally, App. A describes the CINC/J-4s' current involvement in ammunition tracking and requirements planning, and App. B describes the joint and service data and analysis systems for conventional ammunition management.

II. WARTIME MANAGEMENT OF JOINT AND CRITICAL AMMUNITION

This section first describes the major features of ammunition management, especially those relevant to joint operations. It then discusses how the uncertainty of war complicates the CINC/J-4's missions. Finally, it defines the general types of data, knowledge, and analytic tools needed by the CINC/J-4 staffs to fulfill their wartime roles for conventional ammunition.

JOINT ASPECTS OF AMMUNITION MANAGEMENT[1]

Hundreds of kinds of conventional ammunition exist, ranging from bullets to high-technology torpedoes and missiles. Many munitions are used in common by the services; others are unique to one service.[2] Most ammunition has uses for which it is "best," but other types of ammunition are often substitutable for the preferred one. "Preferred" ammunition typically offers greater accuracy, lethality, or range, for example, thus providing greater effectiveness or safety in its delivery.

In peacetime, ammunition requirements are determined through extensive requirements analysis processes—long, slow efforts in the planning, programming, and budgeting system cycle that involve negotiation and compromise.[3] Similar detailed processes are used by the services in the deliberate planning process associated with the development of operational plans (OPLANs). But during wartime or in crisis planning situations, the theater elements have simple planning factors (for example, expenditures per sortie factors) that they can use fairly quickly to estimate ammunition requirements for planned or potential

[1]This short, theater-oriented summary of conventional ammunition is taken largely from Moore, Strucker, and Schank, *Wartime Roles and Capabilities.*

[2]Of the 64 munitions items reported by at least one unified command as "critical" in 1986, 35 were used by more than one service, and 3 of the 12 threat-oriented items were used by more than one service. Of the 35, 9 were common between the Navy and the Air Force; 24 of the 35 were common between the Army and the Marine Corps.

[3]Descriptions of the Navy, Air Force, and Army's munitions requirements process can be found, respectively, in Gerald Sumner, *Conventional Munitions Requirements Estimation in the Navy*, The RAND Corporation, N-2853-P&L, April 1989; Gordon Crawford, *The Air Force's Munitions Requirements Process (The Nonnuclear Consumables Annual Analysis)*, The RAND Corporation N-2821-P&L, March 1989; Kenneth Girardini, *The Army's Conventional Munitions Acquisition Process*, The RAND Corporation, N-2864-P&L, July 1989.

operations.[4] In wartime, requirements would be calculated by the forward battle groups, brigades, or air wings—that is, by the fighters, not by the supporting organizations.

The system for bringing ammunition to the U.S. combatants in a theater of operations originates with either the single manager for conventional ammunition (SMCA)[5] or a service's own ammunition acquisition organization. Ammunition may be stored at numerous echelons between the procuring/producing organizations and the combat units—including service-specific sites in the continental United States (CONUS) and in the theaters of operations (for example, maritime prepositioned ships, Army theater storage areas, or corps storage areas). Depending on geography and interservice arrangements, common-user ammunition might stay in the Army's hands as far forward as ammunition supply points, where they are drawn by other services. But in many cases, the services manage the entire forward movement of their ammunition.

Each service has a centralized ammunition control point with worldwide responsibility. The ammunition control points handle interactions between their services and the SMCA, and they coordinate the distribution of available ammunition among CONUS storage locations and the major operating commands. They work with the Military Traffic Management Command (MTMC) to arrange transport to their service's CONUS storage locations and to ports of embarkation. In wartime, they provide or obtain ammunition in response to requisitions from theater components. The Military Airlift Command and (primarily) the Military Sealift Command provide intertheater transport, which is coordinated by service ammunition control points in the theaters. Ammunition can be called forward from the next higher source of supply, through requisition, by virtually any service echelon in the theater.

The peacetime procurement and initial distribution of ammunition is handled or coordinated by the individual services. But ammunition has numerous "joint" aspects. Certain types of ammunition are used by more than one service, or, in many cases, some distribution, storage, and maintenance functions are performed by one service in support of

---

[4]For example, field manual (FM) 101-10-1 contains situationally dependent ammunition consumption rates for Army units and equipment. Order 8010 has similar factors for the Marine Corps.

[5]The SMCA, headquartered in Rock Island, Illinois, is part of the Army's Armament, Munitions, and Chemical Command. It manages the acquisition, production, and wholesale storage of most ammunition used by more than one service. In fiscal year 1988, this amounted to approximately half the Army's expenditures for conventional ammunition, more than a fifth of the Air Force's, and approximately a sixth of those for the Navy and Marine Corps combined.

other services. Also, certain high-technology munitions, deemed crucial to the successful conduct of operations, are commonly classified as war stoppers. The available quantities of these "critical" munitions are often less than the anticipated requirements, resulting in the need to monitor their stockage levels and use closely.

The joint and/or critical aspects of certain ammunition means that the CINCs' logistic staffs must be actively involved in tracking those assets within the theater and in allocating them to support the CINCs' operational goals and objectives.[6]

Based on initial observations at USPACOM and USCENTCOM, we believe that the CINC/J-4s do not have nearly the full range of capabilities necessary to support the CINC adequately in wartime.[7] Although they have plans to receive selected data from their service components in wartime and they have developed some models to aggregate and display those data, they are currently ill-prepared to face the problems that will arise because of the uncertainties of war. We describe next some of the problems caused by wartime uncertainties.

THE WARTIME PLANNING PROBLEM FOR THE CINC/J-4

The wartime roles of the CINC/J-4 staff require that the staff be concerned with two general time frames: today and the next few days, for current operations; and "next week" or whatever specific planning period for which the CINC is currently thinking about and comparing options. For these two time frames, the staff must have and must understand estimates both of the availability of critical resources and of the requirements for those resources. These estimates must reflect the uncertainties associated with wartime operations and environments.

One certain characteristic of war is that operations will be dynamic, with the overall environment influenced by numerous uncertainties. Uncertainty will exist about the enemy's force strength, intentions and actions; the operations necessary to counter enemy activities; the reliability and effectiveness of weapon systems and munitions; the consumption and attrition of resources; and the support provided by our allies. Uncertainties will also affect communications, resulting in the

---

[6]Involvement with critical ammunition also occurs at the JS level. For example, when a theater component's combined requirements for ammunition exceed supplies, available resources from other theaters may be reallocated by the Joint Materiel Priorities and Allocation Board.

[7]A set of wartime roles for the theater CINCs' logistic staffs and an appraisal of the current capability to fulfill those roles is contained in Moore, Stucker, and Schank, *Wartime Roles and Capabilities.*

loss, delay, or corruption of information critical to commanders and their logistic staffs.

The planning problems caused by wartime uncertainties are characterized in Fig. 1. On any given day (for example, "Today" in Fig. 1), the CINC/J-4 staff needs to understand how much stock is available in the theater. However, stockage data may not have been received from the components and other organizations for some period of time because of communications problems or data processing constraints. Looking back from the current time period to the point when reliable stockage data were last available, the CINC/J-4 staff faces uncertainties about how much stock was consumed in conducting recent operations, how much was lost because of enemy actions, and how much was received through resupply from outside the theater. Therefore, the "exact" stock position is unknown, and the best the J-4 staff can do is to tell the CINC the "most likely" range of available stock.

The range of uncertainty for stock on hand becomes wider as the CINC/J-4 staff looks into the future. Accurate forecasts of available stocks for planned, near-term operations are severely hampered because of variability in consumption rates, losses to enemy actions, and resupplies. Furthermore, the effects of uncertainty on munitions availability predictions are increasingly aggravated as longer planning horizons are considered.

The important information in Fig. 1 for the CINC and his staff is the prediction band's position. If the interval falls completely in the

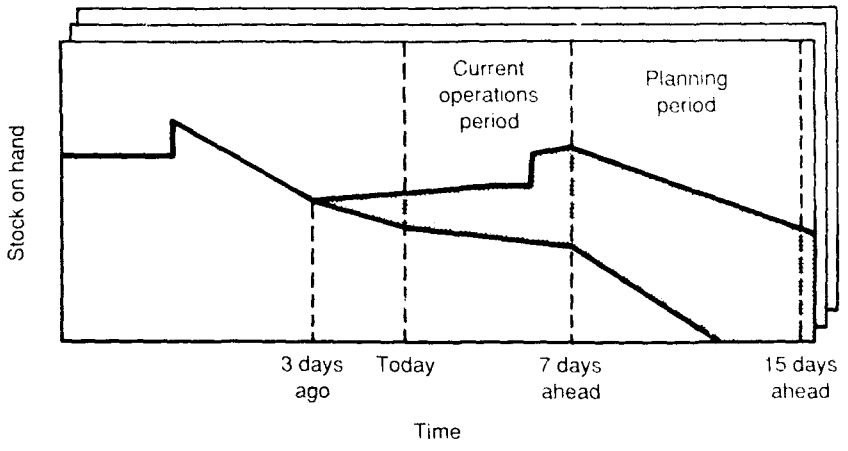


Fig. 1—The uncertainty of logistic resource sustainability

positive stock range, as does the shaded band at seven days, then planners can "confidently" depend upon sufficient assets within the theater to support the planned operations. On the other hand, if the stockage interval is completely negative at a point in time, then the planned operations cannot be supported unless actions are taken to increase theater stock levels or to decrease consumption rates. The interim position, where part of the band lies in the positive area and part in the negative area, suggests that enough stock *may* be available to support operations, but that the possibility of insufficient resources exists.

To develop charts like Fig. 1,[8] the CINC/J-4 staffs need relevant data and the ability to estimate or forecast stock availabilities and requirements. We describe next the general types of information and models the CINC/J-4 staffs need.

GENERAL INFORMATION AND MODEL REQUIREMENTS

We categorize what is necessary to monitor and manage effectively theater ammunition assets as data, knowledge, and analytic tools. *Data* represent values that are changing as the war progresses. Data are very dynamic, reflecting the continuous expenditure and receipt of stock and the evolving operations. These values cannot be generated by the CINC/J-4 staff, but must be received from outside organizations. Various items of data address both the availability of assets and the requirements for those assets: They include stock levels within the theater, stock en route to the theater, and information on current force strengths, missions, and operations.

Knowledge is more static in nature. It represents various factors that are "known" before the war begins (although many knowledge factors may change as the war progresses) and rules for applying them. Where the data are received from other organizations, the knowledge is resident at the CINC/J-4s. At times, data are used to update the knowledge factors as experience (new knowledge) is gained during wartime. Knowledge includes such things as lists of ammunition that are used by more than one service, lists of substitute ammunition with appropriate effectiveness ratios, and lists of requirements for ammunition movement, handling, and storage.

[8]Charts similar to Fig. 1 should be developed for each logistic resource of interest so that the CINC can understand the sustainability of current operations and supportability of planned operations. These resources include several different types of ammunition, various end items (such as aircraft, tanks, or ships), and fuel.

Certain types of knowledge, such as consumption factors for different types of operations, could be used by the CINC/J-4 to generate ammunition requirements estimates. Other types of knowledge, such as the common and substitute munitions, could identify alternatives or options for overcoming supportability problems. Finally, certain types of knowledge, such as what is needed to move, handle, and store ammunition, could help them understand the ability to implement options for solving supportability problems. These various factors would be organized into a "knowledge base" similar to conventional databases, but having more flexible ways of accessing and relating the knowledge.

Analytic tools represent functional processes between data and knowledge and could be used to develop information for the CINC and the logistic staff. Tools could organize, synthesize, aggregate, and display the various data in ways that quickly capture the status of logistic assets and the ability to sustain and support operations. Figure 1 is an example of the output of a display tool. Other types of tools could help incorporate and elucidate the effects of wartime uncertainties. For example, in Fig. 1, an analytic tool estimates the current stock position and forecasts future stock availabilities given that relevant data are lacking. Finally, analytic tools could help to update and modify the knowledge base as additional knowledge is gained during the conduct of the war or as enemy actions affect theater capabilities.

Table 1 provides an initial list of the data items, knowledge factors, and analytic tools needed by the CINC/J-4 to fulfill its four wartime roles. This list is based on numerous interviews with personnel and organizations at the JS and at USPACOM and USCENTCOM.

The position of the X's in Table 1 may be arguable. However, we believe that, for any reasonable set of wartime roles, certain types of data, knowledge, and analytic capabilities are needed by the CINC/J-4s if they are to assist their CINCs in planning and coordinating operations. The next three sections describe in more detail these types of data, knowledge, and tools, and compare those requirements with current capabilities at USPACOM and USCENTCOM.

Table 1

DATA, KNOWLEDGE, AND TOOLS NEEDED TO FULFILL THE CINC/J-4 WARTIME ROLES

Information and Tools Needed	Roles			
	Monitor Theater Logistics	Coordinate Logistic Support	Evaluate Proposed Plans	Advocate Theater Support
Data				
Ammo stocks by area	X	X	X	X
Resupply en route	X	X	X	X
Operations	X	X	X	(a)
Threat remaining	X	X	X	X
Knowledge				
Consumption factors	(a)	(a)	X	X
Common/substitute munitions	X	X	X	X
Support factors	(a)	X	X	(a)
Tools				
Requirements estimator	(a)	(a)	X	X
Inventory forecaster	X	X	X	X
Support options generator	(a)	X	X	X
Display package	X	X	X	X

NOTE: CINC/J-4 is the Logistics Directorate in a unified theater command.
[a]Not applicable.

III. WARTIME DATA REQUIREMENTS

In this section, we define in more detail the data needed by the CINC/J-4 to estimate (1) the current and future inventory of ammunition, and (2) the ammunition necessary to support both current and planned or potential operations. We also describe the capabilities that currently exist in USPACOM and USCENTCOM.[1]

First we list the general types of data needed and the ammunition items that should interest the CINC/J-4. Then we define the units of measurement, the aggregation of the data, and the desired frequency for reporting ammunition inventories. Because the CINC/J-4s must address the requirements for ammunition in addition to the current stocks of ammunition, we describe the types of operations and threat data needed in wartime. We conclude by summarizing our recommendations for improvements in the ammunition data area.

GENERAL TYPES OF DATA NEEDED IN WARTIME

The types of data the CINC/J-4 needs to address issues of ammunition availabilities and requirements include:

- Ammunition inventories in the theater, by service, and by geographic region;
- Ammunition stocks en route to the theater, including where and when they will arrive;
- Characteristics of operations, including battle intensity, geographic region, sortie schedules, and so on;
- Types and quantities of remaining enemy threat-oriented targets;
- Changes in theater ammunition storage, handling, and transportation capacities.

The on-hand inventory data would allow the CINC/J-4 staff to understand *current* stockage positions and, with the help of shipment data, to estimate *future* stock availabilities. Data on operations and remaining threat would assist the CINC/J-4 staff in estimating the *requirements* for various types of ammunition. Together, they would allow the CINC/J-4 to identify limitations in supporting operations.

[1]The appendixes contain more details on the current practices and capabilities of the staffs at USCENTCOM and USPACOM and their service components.

Information on specific service inventories, and on the ability to handle, store, and transport ammunition, would assist in discovering theater solutions to local ammunition problems. These data should be available from the service components, other groups on the CINC's staff, and centralized organizations such as USTRANSCOM and the SMCA.

THE RANGE OF AMMUNITION ITEMS OF INTEREST

The various services use thousands of different types of ammunition and ammunition components. Although each service maintains inventory data on the wide range of munitions it uses, the CINC/J-4 needs data from each component on only a limited subset of ammunition. Duplicating the full range of service inventory data at the joint level would overwhelm the limited CINC/J-4 staff and is not necessary for the higher level roles and functions performed at the unified level.

Currently, the CINC/J-4 staffs request data from their service components on a limited number of munitions. These *critical items,* which vary for different OPLANs, have theater inventories below a desired level and/or are felt to be crucial to the successful conduct of operations.

We believe these lists should also include munitions common to more than one service (or to allies), especially items on one service's critical list but not currently on the other common-user service's list. These data on stock availability of common-user items would enable the CINC/J-4 staff to evaluate the potential of overcoming shortfalls in one service by "cross-leveling" from the inventory of another service.

GEOGRAPHIC AGGREGATION

Another change we recommend is that the geographic distribution of critical item inventories be identified. Currently, the components report total assets in the theater, not distinguishing where those assets are located. For large theaters, such as the Pacific Command, the CINC's staff should know how those assets are distributed across the theater. For example, knowing there is a 20-day supply of a particular munition in the theater suggests that no problems in supporting near-term operations should exist. However, if the ammunition is stored in Korea when it is needed for operations in Vietnam, the CINC/J-4 staff will need to examine options for transporting the ammunition to Vietnam.

UNITS OF MEASUREMENT FOR REPORTED ITEMS

Ammunition is typically categorized as either level of effort (LOE) or threat oriented (TO). Requirements for LOE munitions, which are general-purpose munitions, are determined on the basis of estimates of expenditure rates and assumptions about the distribution of combat intensity and posture—for example, attack, defense, disengaged. In contrast, requirements for TO munitions are based on counts of enemy targets (for example, enemy aircraft or bridges), allocation of those targets to U.S. force elements (for example, ground-based air defense or fighter aircraft) using specified munitions, and assumptions regarding skill and opportunity in acquiring and destroying the assigned targets.

In both peacetime and wartime, the available supplies of LOE ammunition are typically measured in terms of "days of supply" (DOS), reflecting how long current stockpiles would last under assumed expenditure rates. Available supplies of TO munitions are measured in terms of "percent of requirements," reflecting the remaining fraction of the *objective* stockpile—that is, of the number of weapons originally estimated to be *required* to destroy a fixed number of targets.

Current plans call for the service components of USPACOM and USCENTCOM to provide ammunition data to the CINC/J-4 staff in terms of numbers of rounds ("eaches"), DOS, or percent of requirement.[2] The latter, operationally oriented metrics potentially convey greater meaning. However, computational and interpretation problems suggest that the service components should *also* report the number of rounds for the critical ammunition items. The CINC/J-4 can then verify the substance and the validity of the operational measures.

Day-of-supply figures, as mentioned previously, are based on expenditure rates for particular operational postures; a DOS for offensive operations represents a different quantity of ammunition than a DOS for defensive or disengaged operations (that is, not all "days" are the same). At present, the CINC/J-4 staffs don't know what the service components have assumed about force employments, combat intensities, or expenditure rates when calculating DOS figures.

The percent-of-requirement figures for TO munitions have similar problems. During peacetime, the percent-of-requirement figure represents the ratio of stocks available to stocks needed based on the

[2]The specific procedures vary somewhat among unified commands. The components at USPACOM will submit *total OPLAN requirements* for TO and LOE munitions and the CINC/J-4, based on knowledge of the OPLAN's length, will calculate the quantity of ammunition that comprises a DOS. They then use this metric to convert inventory stock to the appropriate number of days of supply. At USCENTCOM, on the other hand, components will submit inventory data using their DOS and percent-of-requirement metrics.

number of targets or enemy threat. In wartime, the metric reported by the service components reports a decrement in the numerator, as ammunition is expended, but does not reflect changes in the "requirement" (the denominator) as the war progresses. Therefore, the percent-of-requirement figure reported by the service components is always decreasing as the war progresses[3] (unless, of course, resupply increases the quantity available).

These problems might be solved by having the service components correct the percent-of-requirement calculation to reflect remaining threat, and provide greater knowledge to the CINC/J-4 staff on the "meaning" of the DOS figures. However, to assess the supportability of the CINC's own operational plans, the CINC/J-4 staff is better off comparing ammunition requirements (estimated using consumption factors described in the next section) with the number of available rounds of ammunition. Therefore, the CINC's staff needs data on eaches as well as the DOS and percent-of-requirement metrics. With data on the number of rounds, and the appropriate relationships and factors, the CINC/J-4 staff can generate its own DOS and percent-of-requirement figures for any number of different types of operations.

FREQUENCY OF DATA REPORTING

Currently, the service components of USPACOM and USCENTCOM report ammunition inventory status in peacetime in response to requests from the CINC/J-4 staffs. The CINC/J-4 staffs also have some access to regular reports generated by the services' centralized ammunition management systems.[4] We believe that periodic peacetime reporting should be formalized for at least two reasons. First, reporting procedures in peacetime can aid in identifying problems that may arise in data definition and interchange, and in refining the reporting procedures in wartime. Second, the peacetime inventory data are necessary for wartime planning and as a database of initial values if a war begins. For these reasons, the service components should report in-theater inventory status to the CINC/J-4 staffs on a scheduled basis, possibly quarterly, in peacetime.

To have the most current inventory data in wartime, we believe the service components should provide data to the CINC/J-4 *whenever*

[3]During wartime, if a TO munition was more effective than expected, so that the expenditure of 40 percent of the stockpile destroyed 50 percent of the required targets, then conceptually the remaining stockpile might be judged *more* adequate than was the stockpile as it stood on D day (if acquisition and kill probabilities have remained constant).

[4]Appendix B describes the various services' ammunition inventory systems.

they have information on a *change* in stock position for a joint or critical ammunition item. This will most likely necessitate daily reports, although at times reports may be needed more frequently, because of sudden losses of ammunition stock caused by enemy attack, or less frequently, because field units have not reported their asset positions because of communication or data processing problems.

To facilitate data interchanges in wartime and to resolve problems in the data interfaces, we also believe that the CINC/J-4 and the service components should decide on a single suitable format and medium for reporting ammunition inventory data. Some service components have developed personal computer– (PC-)based spreadsheet tools for monitoring in-theater stock. The J-4 staffs at USPACOM and USCENTCOM also have this capability. When both the service components and the CINC/J-4 staff are using computers, all data interchange should be on a medium (for example, floppy disk) that minimizes the data entry operations.

Specifying an appropriate data format and interchange medium is important for at least two reasons. First, the CINC/J-4 staffs are typically sparsely manned (for example, at most three to five personnel would be assigned to the CINC/J-4 ammunition branch in wartime at USCENTCOM and USPACOM). Given the range of functions they must perform, every effort should be made to minimize the time consumed on data entry tasks. Second, eliminating manual data entry operations will reduce errors in the data input process. Efforts should be made to take advantage of any common personal computers and software packages that exist among the CINCs' staff and the service components.

RESUPPLY DATA

Data from the components about assets in the theater would help the CINC/J-4 understand the *current* stock position of items on the critical-item list. But the CINC/J-4 must also be able to look ahead and forecast what assets will be in the theater in *future* time periods. This means that the CINC/J-4 must receive data on the anticipated resupply shipments of critical ammunition. These data should include the expected number of rounds, when the shipment is expected, and its destination. Also, because of the possibility of losses resulting from enemy attack, the CINC/J-4 should receive an assessment of the probability of the shipment actually arriving.

Currently, the staffs at USCENTCOM and USPACOM receive, at best, only partial resupply information, and they are unsure about who

could provide complete visibility on resupply shipments. Efforts should be made to establish the necessary data interfaces, most likely with USTRANSCOM or MTMC (who manage port facilities), to ensure that data on ammunition resupply will be forwarded to the CINC/J-4 staff in wartime.[5]

OPERATIONS AND THREAT DATA

Data on ammunition stocks in theater and en route to the theater would allow the CINC/J-4 to estimate the *availabilities* of ammunition assets; the CINC/J-4 also needs data to use in estimating the *requirements* for ammunition. The estimates of ammunition requirements can be generated by combining data on the types of ongoing and planned operations, the numbers and types of enemy threat-oriented targets, and the appropriate consumption factors for LOE and TO munitions.

At USCENTCOM and USPACOM the assessments of ammunition requirements for operations are made primarily by the service components. However, if the CINC/J-4 staffs are to provide the CINC with supportability estimates for current and planned operations (role 3), they must be able to address both sides of supportability—what resources are needed as well as what resources are available. We are not suggesting that the detailed requirements models and calculations used by the service components be duplicated at the unified level. As is the case with defining the subset of items for reporting inventory data, such detailed calculations would overwhelm the limited CINC/J-4 staff and are not necessary at the unified level. However, the CINC's staff should have the ability to generate at least first-order approximations of requirements for joint and critical resources.

Operational and threat-oriented data should be available from the CINC/Operations Directorate (J-3) and from the CINC/Intelligence Directorate (J-2), respectively. The main issue that must be resolved is the detail in which such data are reported.

For TO munitions, the appropriate metric is probably the number of enemy targets (or threat) remaining in the appropriate geographical region. The number of targets can be combined with the numbers and types of munitions needed to defeat those targets to generate ammunition requirements.

---

[5]The Army's movement management system—redesign, when fielded, will provide information on cargo in transit to the transportation commands and to the execution levels of the Army. This system should have the ability to provide the types of data the CINC/J-4 needs.

For LOE ammunition, the metric used to report current and planned operations must be consistent with the units of measurement of the corresponding consumption factors. That is, if consumption of ammunition is calculated using a rounds-per-weapon-per-day factor, then operational data must reflect the number of weapons. As an example, the operational data for Army or Marine Corps operations might be reported as the type of operation (offense, defense, disengaged), the intensity (light, medium, heavy), and the number and types of forces (so many tank battalions, infantry divisions, and so on). Air Force and Navy air operations might be reported as the number of various types of sorties (defense suppression, close air support, and so on); Navy data might detail the number and types of ships. When a knowledge base of consumption factors is developed based on inputs from the service components, the appropriate form of the operational data requested from the CINC's operational planners can be specified more precisely.

AMMUNITION SUPPORT DATA

At times, imbalances of ammunition will exist within the theater. Ammunition may be positioned in one area of the theater while it is needed in another area, or one service component may require ammunition that is in the possession of another component. The essence of role 2 is solving such imbalances by cross-leveling ammunition between components or geographic regions.

To implement cross-leveling actions, the CINC/J-4 staffs need to understand if sufficient resources are available to move, handle, and store the ammunition (the next section will discuss the factors necessary to know "how much" movement, handling, and storage are needed). During peacetime, the service components can provide to the CINC/J-4 staff the quantities of support assets available in the theater. These baseline values will change as the war progresses because of enemy actions or the introduction of new personnel and equipment into the theater. The CINC/J-4 staffs need the components to forward to them data on such increments or decrements so they can understand if support resources are available to accomplish munitions transfers.

SUMMARY OF DATA REQUIREMENTS

In summary, the following data items are needed by the CINC/J-4 staff in wartime:

- The number of rounds currently in various geographic regions of the theater for a specified subset of ammunition items;

- The number of rounds due into the theater for those selected munitions, including when and where they should arrive plus the probability of their arrival;
- The number of enemy targets remaining in different regions of the theater;
- The types of ongoing and planned operations, including the intensity of the operations and the forces involved in the operations;
- All changes in theater ammunition storage, handling, and transportation capacities.

Most of the above data are currently being collected by the CINC/J-4 staff or are available from the service components, other groups on the CINC's staff, or central organizations such as USTRANSCOM and MTMC. The CINC/J-4 staff must take actions to define the appropriate list of items and units of measurement, and to establish the necessary data interfaces and exchanges.

IV. WARTIME KNOWLEDGE REQUIREMENTS

The data the previous section described are very dynamic, evolving as the war progresses, and must be forwarded to the CINC/J-4s from other organizations. Although certain data, such as initial stock levels, are known when the war begins, the uncertainties of war make predicting with any accuracy what stock levels or operational plans will be in the future difficult. However, another set of values or factors is more static in nature. These values will not change, or will change infrequently, during the war's course. We group these more static factors under the general term *knowledge*.

This section describes the various components that would comprise the knowledge base available to the CINC/J-4s. It lists and defines the various factors, describes how they would be used in performing the hypothesized wartime roles, and discusses how the knowledge base would be created in peacetime and updated in wartime.

GENERAL TYPES OF KNOWLEDGE NEEDED IN WARTIME

Just as data are needed by the CINC/J-4 to understand the quantities of ammunition available within the theater and the quantities of ammunition required to perform operations, so too are various types of knowledge needed. These knowledge components would help the CINC/J-4 estimate requirements, identify potential solutions to supportability problems, and understand what support resources are necessary to implement those solutions. These knowledge components include parameters and the appropriate rules for applying those parameters.[1] These parameters and rules would be organized in a knowledge base resident with the CINC/J-4 staffs and updated periodically based on the data received from other organizations.

The specific types of factors that comprise the knowledge base include:

[1]Parameters are simply numbers or factors; rules are specifications of how and when to apply the parameters in specific cases. For example, a rule may state, "If attacking radar sites with good weather conditions, then three SHRIKEs missiles can substitute for one HARM missile." The three-to-one ratio is an example of a parameter.

- *Consumption factors,* including LOE factors for different types of operations and TO estimators for various types of targets or enemy threats;
- *Commonality factors,* including the types of ammunition used by more than one service (plus necessary interface requirements) and the types of ammunition that can substitute for other types of ammunition;
- *Support factors,* including the amount of resources needed to store, handle, maintain, and transport quantities of various types of ammunition.

Each of these general types of components is described in more detail below.

CONSUMPTION FACTORS

The CINC/J-4 staffs currently do not have factors for estimating ammunition requirements for operations. Rather, they rely on their service components to perform the necessary calculations and provide the results. In this mode, the CINC/J-4 acts merely as an interface, passing service estimates of supportability on to the CINC. However, if the CINC/J-4 is actively to assist the CINC in assessing the supportability of planned operations, and at times to perform this function before service components become involved, it must have the ability to estimate requirements.

All the services have detailed procedures and models that are used in peacetime during the munitions requirements determination process.[2] They also have more approximate factors for quickly generating ammunition requirements for imminent operations. The CINC/J-4s should have access to a subset of these latter, more aggregate factors in their knowledge base. Again, we do not espouse that the CINC's staff have all the detailed capabilities and data that exist at the component level; this would overwhelm the limited CINC/J-4 staff and is not necessary for the higher-level planning at the joint operations level. They should, however, have the ability to generate "first-cut" estimates of the ammunition requirements for operations that are in the initial planning stages.

---

[2]Descriptions of the Navy, Air Force, and Army's munitions requirements process can be found, respectively in Sumner, *Conventional Munitions Requirements Estimation;* Crawford, *The Air Force's Munitions Requirements Process;* and Girardini, *The Army's Conventional Munitions.*

The specific form of the consumption factors in the knowledge base would be a function of the type of factors available from the service components. For TO munitions, the values should be segregated by target type and munition. For example, some values may describe how many AIM-9 missiles are needed to defeat a MIG-23 or how many HARM missiles are needed to render a radar site inoperable.[3]

The specific LOE consumption factors would probably be specified by the type of forces, type of operation and posture, and intensity of operations. For example, there may be a factor for the number of 155-millimeter (-mm) shells required daily for an artillery battalion fighting in a heavy defensive posture, or a factor for the number of Maverick missiles per Air Force close-air-support sortie. Again, the specific values will be a function of what is used by, and available from, the individual components.

We stated earlier that the knowledge factors are primarily static and would change little as the war progressed. However, at least the consumption factors *should be updated* based on the consumption actually experienced during the course of the war, especially during the early stages of a conflict.

Consumption factors for newer types of munitions are typically based on assumptions, engineering estimates, and large combat-oriented simulation models.[4] The service consumption factors for "older" ammunition are based on data from previous wars, subjectively modified to account for new weapon systems, tactics, and enemy threats.[5] Although published consumption factors have many subjective aspects they are the only values available and should serve as the initial consumption rates in the knowledge base. The experience gained during the war should be used to update these initial values. The next section discusses an adaptive consumption factor modifier.

---

[3]Such TO factors may be specified for only the "preferred" munition for various target types or may be specified for the preferred munition and substitute munitions. The latter case is described below under commonality values.

[4]Studies by Lt. Col. B. F. Landrum, *(An Analysis of the Army Conventional Ammunition Rate Studies,* U.S. Army War College, Carlisle Barracks, Penn., April 1982), B. M. Davall, *(Artillery Firing Rates: A Special Report for the U.S. Army Human Engineering Laboratory,* Armament Systems Inc., September 1981) and the U.S. Army's Studies and Analysis Directorate (*Ammunition Planning Factor System [APFS]: Study Draft Report,* January 1987) all describe the development of Army firing rates and the problems that exist with the use of "standard" ammunition consumption factors.

[5]For example, the foreword to FM 101-10-1 states: "The previous edition of FM 101-10-1 has been criticized for the historical nature of the data it presents: i.e., much of the data are based on World War II and the Korean War experience." The FM goes on to state: "The historical data, when used for its intended purpose, must be tempered by judgement and experience, to be considered valid."

COMMONALITY FACTORS

Limited defense budgets constrain the availability of ammunition, especially of expensive TO munitions. Inevitably, service components will run short of needed ammunition resources, putting the supportability of operations in question. When such problems occur, the CINC/J-4 staffs need ways to identify options for solving the supportability problem. Factors in the knowledge base would help them determine if other types of ammunition could substitute for the "preferred" ammunition or if other services use the ammunition that is causing the problem. In these latter cases, cross-leveling options could be considered. For example, the Army may have sufficient stock of an ammunition item in short supply in the Marine Corps, or the Navy may have munitions the Air Force could use to conduct operations. Identifying and exploiting such options is the essence of role 2.

The commonality factors in the knowledge base would comprise two "lists" with supporting information. One list would contain common-use ammunition; the other, substitutable ammunition.

The common-use list includes ammunition common to two or more services. For example, the list might show that both the Air Force and the Navy use AIM-9 missiles or that all services use 30-caliber bullets. But merely knowing that ammunition is common is not sufficient; the CINC/J-4 must also know what is required for one service to use the ammunition of another service—what *interface requirements* exist between the munition and the weapon system that uses the munition.

Weapon system interface requirements are probably not an issue for LOE ammunition. The majority of common LOE ammunition involves the Army and the Marine Corps. Both these services use the same or very similar weapon systems (the Army actually acts as procurement agent for many Marine Corps weapon systems). However, TO munition commonalities will primarily involve Air Force and Navy weapon systems, and these weapon systems may have unique interfaces with their weapons. These interfaces include how the munition is actually connected to the weapon platform and how information and data are passed between the munition and the weapon system electronics. The CINC/J-4 must know if the Air Force can actually use a Navy munition and what is necessary to facilitate such interoperability.

The second list in the knowledge base would involve substitute ammunition. Each preferred munition would be referenced to one or more potential substitutes. For example, HARM missiles may be the preferred munition to attack radar sites, but SHRIKEs could also be used. Just as for common ammunition, substitute ammunition entries need to include some additional information. To know that SHRIKEs

can substitute for HARMs is insufficient; the CINC/J-4 should also understand *how many* SHRIKEs are needed to substitute for one HARM—it should have knowledge of effectiveness ratios.

The CINC/J-4s currently have only portions of the necessary knowledge, at best. For example, USPACOM has a list of ammunition common to the Air Force and Navy (which reportedly was received from the European theater). The complete range of knowledge factors should be available from other organizations. The SMCA should have visibility of common and substitute ammunition. Each service could provide weapon system interface requirements for common munitions, and peacetime tests could be run to examine interoperability problems and ways to solve these problems. Finally, the SMCA and/or the services should have knowledge about effectiveness ratios for substitute munitions. A concerted effort in peacetime could succeed in compiling and organizing the various commonality values in the knowledge base.

The commonality factors should be very static and change only when new weapon systems or ammunition are introduced, or when evolving tactics or enemy actions suggest such changes are necessary. Therefore, the knowledge base should require only occasional maintenance and update.

SUPPORT FACTORS

If supportability problems exist and if inter- or intratheater transfers are a viable alternative to solving these supportability problems, the CINC/J-4 must know if the transfer is actually accomplishable—that is, the CINC/J-4 must understand what resources are necessary to move, handle, and store the ammunition and whether those resources are available at the right locations within the theater. Factors contained in the knowledge base would provide the information to the CINC/J-4 staff on the necessary support assets. Data from the service components would indicate which assets were available.

The knowledge factors for movement, handling, and storage would be described with some common metric, such as tons. For example, the knowledge base may indicate that 1000 rounds of 155-mm ammunition weighs 25 tons and requires specific handling equipment and personnel. By consulting the knowledge base, the CINC/J-4 could assess what is needed to transfer 5000 rounds from Korea to Vietnam.

The CINC/J-4s currently do not have such theater support factors, although such information should be available from their service components. Support factors could be organized in peacetime, probably with minimal effort. These factors should not change during the war

and, therefore, the support values in the knowledge base would seldom—if ever—undergo updating.

DEVELOPING THE INITIAL KNOWLEDGE BASE

The initial knowledge base should be developed in peacetime so that it is available if a war begins. The values that make up the knowledge base are typically available from organizations within the theater or from centralized organizations such as the SMCA. The main effort in developing the knowledge base involves collecting and organizing the various factors. The majority of the knowledge base would be common to all theaters so a concentrated effort, perhaps on the part of the JS/J-4, would result in a set of values with widespread use.

Although the knowledge base would primarily be used by the CINC/J-4, it could also provide helpful information to the theater service components. With visibility of common ammunition, services operating in proximity could recognize potential solutions to their immediate ammunition problems. In such cases, the services might bypass the CINC/J-4 and work out arrangements among themselves. Of course, the CINC/J-4 should be apprised of such cross-leveling so it can adjust the appropriate data on stock availabilities and consumption.

SUMMARY OF KNOWLEDGE REQUIREMENTS

The JS/J-4 and the various theater CINC/J-4s should work together to develop a knowledge base. They should interact with the SMCA, the appropriate service organizations, and the theater components to assemble, organize, and promulgate the following types of information:

- Consumption factors, including LOE factors for different types of operations and TO factors for various types of targets or enemy threats;
- Commonality factors, including ammunition used by more than one service and ammunition that can substitute for preferred ammunition;
- Support factors, indicating what is needed to move, handle, maintain, and store different types of ammunition.

Data and knowledge by themselves, however, are not sufficient to allow the CINC/J-4 to deal adequately with the uncertainties of wartime and to assist the CINC in understanding the sustainability and

supportability of operational plans. Analytic tools are needed to bring the data and knowledge together in meaningful ways. The next section describes the necessary set of such analytic tools.

V. ANALYTIC TOOL REQUIREMENTS

The data values and knowledge factors the previous two sections described are just numbers. The uncertainties of war and the volume of data demand methods to transform the raw values and factors into information useful to the CINC. The CINC/J-4 needs a set of analytic tools or models to estimate adequately munitions availabilities and requirements, to identify supportability problems, to recognize potential solutions to those problems, and to present results or options to the CINC in meaningful ways.

This section describes the analytic tools we believe the CINC/J-4 needs. We first list the general types of tools necessary and then briefly describe each. The section also describes the interaction between the data, knowledge, and tools that results in the information the CINC and his operational planners need. The section concludes by presenting a brief overview of several analytic tools currently under development at the JS level or by a specific theater's J-4 staff.

GENERAL TYPES OF TOOLS NEEDED IN WARTIME

The types of analytic tools the CINC/J-4 needs in wartime to provide the CINC with the necessary information on the supportability and sustainability of operations include:

- A *consumption factor modifier,* which would use recent combat experience to update and adapt the ammunition consumption factors in the knowledge base;
- An *ammunition requirements generator (ARG),* which would estimate approximate ammunition requirements to support and sustain operating options;
- An *ammunition inventory forecaster,* which would estimate current stock position and predict future stock availabilities;
- A *support options generator,* which would identify and evaluate options for overcoming ammunition resource shortfalls;
- A *flexible display package,* which would aggregate and display disparate information in ways meaningful to the CINC and his operations planners.

These analytic tools would serve two purposes. First, they would allow the CINC/J-4 staffs to deal with the various uncertain events

that occur during wartime. Unexpected ammunition consumption rates, either higher or lower than planned, would be used to update the original factors. Extrapolating from known stockage positions would help the staffs overcome the unexpected disruption of data inputs from the service components. Second, the analytic tools would be used to synthesize, aggregate, and display in various formats information vital to the CINC and his operations staff in planning future operations. These displays would also incorporate the various types of uncertainty that surround estimated availabilities and requirements.

We believe that these analytic capabilities should be derived from several well-integrated, special-purpose models rather than from a single complex model that attempts to embody numerous capabilities. In this way, the tools can be developed incrementally, each focusing on a single function or objective. The end result would be a simpler development process with different organizations working to develop separate tools versus one organization attempting to develop a single, all-encompassing model. The modularity would also enhance maintenance and make the system more amenable to future modifications. We also believe that these modular tools can and should be developed on PCs using existing spreadsheet and database software.

We next describe each of the analytic tools in more detail. Although we recommend that several special-purpose models be developed, we recognize that the tools, along with the data and knowledge, must all interact; we follow the individual tool descriptions with a discussion of this interaction.

CONSUMPTION FACTOR MODIFIER

As we described previously, the knowledge base would contain a set of ammunition consumption factors for use in generating the numbers and types of ammunition necessary to defeat enemy targets and threats in support of current and planned operations. Existing service consumption factors are derived from various sources and for various purposes. They may be based on data from previous wars, field exercises, large simulation models, or engineering studies. The factors may also incorporate subjective assumptions. Older types of ammunition have only been used in combat situations that were very different from what is likely in future wars. Newer types of ammunition have never been used in combat at all. The uncertainty surrounding the effectiveness of munitions, especially new munitions, against enemy targets, and the subjective inputs used in developing the published service consumption

factors suggest that these factors may not reflect actual requirements in future wars.

Despite these problems, the existing service consumption factors represent the only measures currently available for the CINC/J-4 to use in generating ammunition requirements. However, combat experience will provide new information to enhance the accuracy of these initial values. Part of the uncertainty surrounding ammunition effectiveness will disappear as we begin to understand how munitions are employed to defeat enemy targets or to support various types of operations. This new information should be used by the CINC/J-4 staffs to update the consumption factors continually.

The modification process would work as follows. The initial knowledge base would contain the "best" estimates of the numbers and types of ammunition necessary to defeat enemy targets and the quantities of various LOE ammunition needed for different categories of operations. After the first several days of the war, the CINC/J-4 will have some idea of the quantities of ammunition expended, the operations those munitions supported, and the targets those munitions defeated. This knowledge would be based on inputs from the service components or on inferences from the data on stock availabilities, operations, and remaining threat. The new information would be combined with the original consumption factors to generate a new set of factors. This adaptation and updating step would use statistical forecasting techniques, such as moving averages, exponential smoothing, regression, or Bayesian estimation.

The modification process, although relatively simple in concept, should not be done without full consideration of surrounding factors and circumstances. Numerous variables may affect the quantity of ammunition expended to defeat targets or to support operations. Such variables include weather conditions, terrain, weapon system and operator effectiveness, and the quantity of ammunition available initially to support the operations. For example, the quantity of ammunition expended may represent the number of rounds the commander had available; if more rounds had been available, more rounds might have been consumed. The consumption factor modifier must be designed to allow for these various contributing factors, but reasonable default values for these extraneous variables must also be built in.

AMMUNITION REQUIREMENTS GENERATOR

To provide the CINC with information on the ability both to sustain current operations (role 1) and to support planned operations (role 3), the CINC/J-4 needs a mechanism to estimate ammunition require-

ments for various types of operations or enemy targets. The ARG could also be used "after the fact" to estimate the quantity of munitions consumed since the last time reliable inventory data were received from the components. Such estimates of ammunition consumption would update inventory status data.

The ARG would combine data on operations and remaining threat with knowledge on ammunition consumption rates to generate the types and quantities of ammunition needed. Again, the model or the user of the model needs to be aware of extraneous factors (for example, the weather, terrain, or enemy strengths) that might exist and to incorporate their potential effect on requirements.

AMMUNITION INVENTORY FORECASTER

Section II discussed how data transmission and processing problems may cause component inventory data to be several days late in arriving at the CINC/J-4. In those cases, the CINC/J-4 would be uncertain about the stock currently available in the theater (see Fig. 1). Also, to estimate the supportability of planned operations, the CINC/J-4 must forecast the stocks of ammunition that will be available in future time periods. A model to forecast inventory levels would be used both to fill in the gaps created by missing or late data and to estimate future stock availabilities.

To develop estimates of current inventory status when data from the services are several days late, the forecasting model would use the latest available information on stock position, data on the operations conducted since the last service inventory report, and data on the resupply of ammunition from outside the theater. The operations data would be combined with consumption factors (in the ARG) to estimate the stock consumed in the intervening time frame. Combining the last available stock position with the estimate of munitions consumed and the data on resupply would result in an estimate of current stock inventories. The uncertainties surrounding consumption and resupply would be combined to develop confidence intervals for the point estimate of current stock availabilities.

To forecast future stock availabilities, the current stock position would be projected based on data on resupply and estimates of ammunition consumption to support upcoming operations. Again, confidence intervals can be developed based on the various types of uncertainties that exist.

As we noted when discussing the other analytic tools, forecasting inventories, though simple in concept, may be difficult in practice

because of the effects of extraneous variables. Some degree of expertise would be necessary to include these extraneous effects in the forecasting process. We believe that this expertise can be built into the inventory forecaster in the form of "production rules." Such rules are often used in expert systems. For example, the inventory forecaster might have a rule of the following form:

> If the type of operation is defensive and if the weather is classified as adverse, then the estimated munition consumption for that operation should be reduced by 30 percent.

Through the use of such rules, the inventory forecaster can be "intelligent," incorporating the knowledge gained during weapon exercises and testing as well as the expertise of personnel who understand how munition availabilities and consumption are affected by various factors.[1]

SUPPORT OPTIONS GENERATOR

When the availability of ammunition and the requirements for ammunition suggest that problems supporting current or planned operations may exist, the CINC/J-4 must consider options for overcoming those problems (role 2). The commonality and the theater support factors in the knowledge base are aimed at helping the CINC/J-4 to identify and evaluate such options. An analytic tool to search the knowledge base and identify cross-leveling or munition substitution options would assist in this function.

The support options generator would be given a "problem" expressed as a service shortfall in a certain type of ammunition and geographic area, possibly relating the problem to a specific type of target. The tool would examine the knowledge base to see if that munition (1) has a potential substitute, and (2) is common to another service. If a substitute is found, the model would identify it along with the corresponding effectiveness ratio. If a common-user service exists, the model would identify the service, along with any weapon system interface requirements. If a "solution" to the problem is identified, the CINC/J-4 could query the database to determine if inventory of the substitute ammunition is available in the theater or if the common-

[1]Although we only discuss the inventory forecaster as having some degree of intelligence, all the analytic tools include similar types of rules. For example, the rule shown is also appropriate for the ARG. Such built-in expertise reduces the burden on the user and helps reduce "blunder factors," ensuring that obvious effects are included in estimates and forecasts.

user service has sufficient stocks to accomplish a cross-leveling action. Once the CINC/J-4 identifies a potential solution to the supportability problem, the support options generator would be used to determine if sufficient capacity exists in the theater to move, handle, and store the ammunition.

If the knowledge base contains only a few factors or if the factors are well organized and indexed, only a data management system may be necessary to identify options in supportability problems. However, a more advanced analytic tool would simplify and enhance the process. Furthermore, if the tools are integrated in the proper manner, the identification of a supportability problem and of a solution to that problem could be completely automated. The CINC/J-4 would receive estimates of stock availabilities and requirements, assessments of supportability with problems identified, and solution recommendations for any problem the models detect. Of course, ultimate decisions would rest with the CINC and the CINC/J-4.

FLEXIBLE DISPLAY PACKAGE

Using the tools described above, the CINC/J-4 could generate a wide range of information. This information relates to different types of ammunition (and other logistic resources, such as fuel, food, spares, and so on), different geographic regions of the theater, and different service components. It must be organized and aggregated in ways that are meaningful to the CINC and to the operations planners. The CINC/J-4 must present and display this information at least daily in status briefings to the CINC.

To accomplish all of this, the CINC/J-4 needs a flexible data display package. This package should be capable of presenting information in various tabular and graphical forms, including stock availabilities and requirements in different regions of the theater, possibly on map-type displays. The package should have standard formats and outputs, as well as the ability to generate special types of information reports and displays as necessary.

The CINC/J-4s have developed techniques to aggregate and display data, but many of these techniques involve simple hand-generation of charts and tables. The CINC/J-4s often have difficulty providing special displays requested by the CINC because of the lack of automated tools. Recent advances in the graphical capabilities of microcomputers suggest that off-the-shelf software may be useful for the CINC/J-4. Producing decision-relevant information is certainly important and necessary but the effective organization and presentation of that information is of equal importance.

INTERACTION OF THE DATA, KNOWLEDGE, AND TOOLS

As we noted earlier, the data, knowledge, and analytic tools are of little value in isolation. They must all be integrated to provide the capabilities the CINC/J-4 needs. Figure 2 summarizes the foregoing discussion of analytic tools, depicting how they will incorporate the data and knowledge discussed in Secs. III and IV. The process is generally as follows:

- Data on *recent* operations (that is, battle intensity and posture from CINC/J-3; other ammunition losses and the disabling of TO targets from CINC/J-2) are combined with consumption estimators in the requirements generator to produce time-series estimates of the amounts, types, and geographic locations of ammunition consumed during the most recent battle period. These estimates are used to "correct" the most recent in-theater inventory reports and develop estimates of current stock position.
- Data on *current* operations are input into the requirements generator to produce time-series estimates of the ammunition necessary to support operations currently under way. The inventory forecaster subtracts these *committed* munitions from the sum of in-transit stocks and estimated current stocks to provide time-series estimates of ammunition stocks during the course of currently planned operations.
- Data on *future* operations alternatives are input into the requirements generator to produce time-series estimates of ammunition necessary to support those alternatives. For each alternative, the inventory forecaster balances requirements against estimated inventories (less current commitments and plus expected resupply from in-transit stocks) to produce a representation of sustainability.
- If ammunition inventories are tight or poorly positioned, the planners may elect to look for substitute munitions, common-user munitions, and/or ammunition redistribution. This activity, depicted in Fig. 2 by the "support options generator" oval, may actually be a collection of spreadsheet models and lookup tables.
- The knowledge base receives ongoing maintenance. Consumption factors are updated to reflect the impacts of recent operations on changes in current inventories. Logistic capacity information (relating to lift, storage, and handling availabilities) needs routine updating.

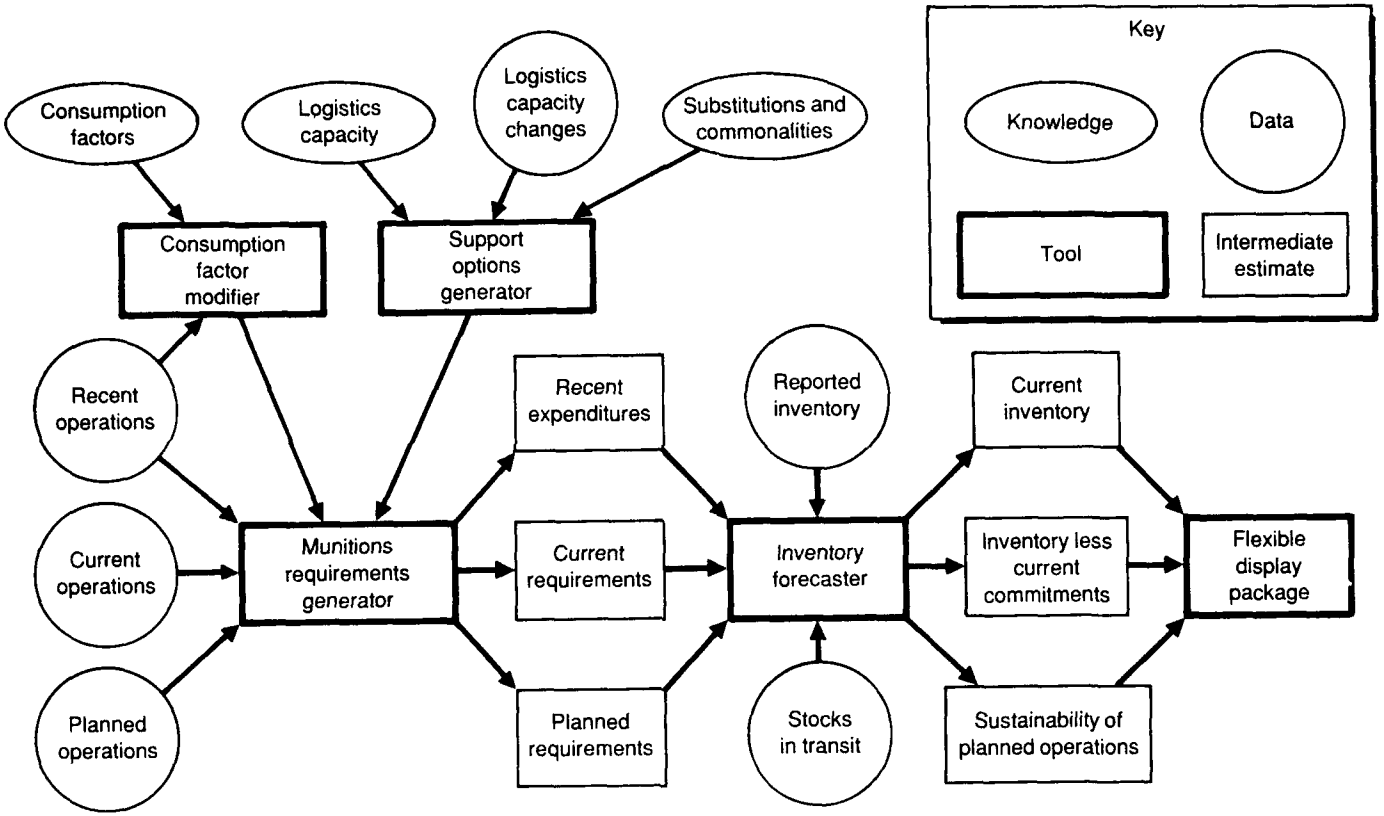


Fig. 2—Interactions of data, knowledge, and analytic tools

The hard-copy and visual display outputs would be designed to capture (1) the distributions of requirements and inventories across time and geography, and (2) the inherent uncertainties in the estimates. These aspects must be depicted in ways that are immediately understandable and operationally relevant.

MODELS CURRENTLY UNDER DEVELOPMENT

Analytic capabilities have already been developed in several unified commands, typically involving PC-based spreadsheet tools that summarize inventory data received from the service components. A more concerted effort is necessary to develop the range of analytic capabilities needed in wartime and to integrate these capabilities to provide the CINC/J-4 with the tools to assist the CINC in planning and conducting operations. Other models are under development at the JS. We briefly describe here three especially relevant models currently under development: General Unified Ammunition Reporting Data System (GUARDS), ARG, and the Command and Control Information System (C2IS). The appendixes provide more details.

The GUARDS[2] is under development for the JS to track munitions inventories held by all services. The appropriate service headquarters submits periodic inputs to GUARDS for a specified subset of munitions. These inputs specify the owners of the ammunition inventories and the inventories' location and status. The data represent ammunition inventories at the reporting moment; they contain no information on scheduled stock resupplies.

The GUARDS will eventually provide inventory data to the CINC staffs, but the inherent delays built into the system will result in somewhat outdated data, especially during wartime as ammunition is being rapidly expended and resupplied. Data received directly from the theater service components should be more timely.

The ARG[3] is a menu-driven, PC-based model under development for the JS that will estimate ammunition requirements for planned operations, compare those requirements with on-hand inventories, and produce graphic displays showing ammunition supportability over the length of the engagement. Its primary use will be in evaluating the

[2]The GUARDS is described in JCS, *General Unified Ammunition Reporting System*, Publication 6, Volume 2, Part 13, Chapter 3.

[3]The ARG is described in JCS, *Memorandum for Attendees, Joint Planning and Execution Systems Conference (JPESC); Subject: Ammunition Requirements Generator*, July 1988, and in C. L. Starkand and J. McNeer, *Continuation and Expansion of the Force Module Logistics Sustainability Model (FMLSM) for the JDSSC: Task 3, subtask 1, Final Draft Functional Description*, Synergy, Inc., February 1988.

supportability of sensitive crisis action plans before service components are asked to assess supportability issues.

The ARG will have some deficiencies for time-sensitive planning by the CINC/J-4 staffs in wartime. The model does not recognize the uncertainty inherent in war (such as losses caused by enemy actions, model perturbations of consumption rates) and it is theater-based—that is, it does not recognize the geographical location of inventory or operations within theaters. It has recently been modified to handle the resupply of ammunition through user inputs specifying the dates and quantities.

The C2IS is an inventory tracking and display system under development at USCENTCOM. It is designed to accept inputs from the service components on combat and logistic resources and display those values on various maps and tables. The CINC, his various directorates, and the service components all may access the data through a communications network.

The C2IS should substantially improve the data collection, transmission, and display capabilities of the CINC/J-4s. It could conceivably provide the foundation for most of the enhancements we have described. As currently conceived of, however, it does not recognize the uncertainty of wartime and cannot analyze the consumption of resources. Also, it "knows" only about assets currently in the theater and has no knowledge of expected resupplies. It does, however, have several impressive features that could be adapted. The networking capabilities allow the rapid input, access, and dissemination of data. The maps, charts, and tables are useful for portraying asset positions.

These methodologies, and various others under development (see the appendixes), will provide some of the needed capabilities for wartime planning. However, they have been developed primarily to benefit the JS during peacetime. What both the JS and the theater commands need are (1) a concerted effort to identify and organize those aspects that will be useful for time-sensitive wartime planning, and then (2) the development of additional capabilities to provide the complete range of data, knowledge, and tools the CINC/J-4 staffs need in wartime.

VI. RECOMMENDATIONS AND FURTHER RESEARCH ISSUES

Our research on the command and control of joint logistic assets in wartime acknowledges that the uncertainties of war, coupled with the constrained availability of logistic resources, will result in conflicts over resources that span multiple services. The unified commander must resolve such conflicts, and must do so in concert with his operational plans and objectives. The CINC's logistic staff must not only provide the information and perspectives to assist in such difficult allocation decisions, but must also have the ability to anticipate when and where logistic supportability problems will arise. Furthermore, the CINC/J-4 staff should be able to identify ways to overcome resource shortfalls.

To provide the assistance and the assessments the CINC needs, the CINC/J-4 staff must continually monitor the availability of stocks in the theater and the requirements for those logistic assets. With estimates of availabilities and requirements, the CINC/J-4 can provide appraisals of the supportability of current operations. But the CINC/J-4 must also be able to look into the future, projecting stock availabilities and requirements, and provide the CINC with assessments of the supportability of operations that are in the planning stage.

In the previous sections, we outlined the data, knowledge, and analytic tools needed by the CINC/J-4 staff in wartime to assist the CINC in assessing the supportability of current and planned operations. We also described the current capabilities of the CINC/J-4 and the service components in USPACOM and USCENTCOM and briefly reviewed several systems currently under development. Although the CINC/J-4s will receive some data from the service components in wartime and have already developed some analytic tools to support their functions, a considerable gap between what will be needed in wartime and what is currently available still exists.

Filling this gap should not be difficult, however, since much of the data and knowledge that will be necessary in wartime exists in service or central organizations' systems. Some near-term improvements could close the gap between what is necessary and what is currently available or will be available through systems under development. In this section we summarize the improvements needed in data, knowledge, and analytic tools to allow the CINC/J-4 staff to access the ammunition supportability of operations.

DATA INITIATIVES

The data the CINC/J-4 staff needs in wartime include information on stocks available within the theater, stocks en route to the theater, and the types and intensity of ongoing or planned operations. These data should be available from three different sources: the service components, other directorates on the CINC's staff, and central organizations such as USTRANSCOM and the SMCA. The CINC/J-4 must define the items of interest, the units of measurement for the data, and the format and media used to report the data. Specifically, the CINC/J-4s should

- Check and refine the list of critical ammunition items to include munitions used by more than one service, especially if these joint munitions are in short supply for a service component.
- Provide the service components with the list of critical ammunition items for each OPLAN and receive data measured in number of rounds available in different regions of the theater.
- Order the data to be reported in wartime on a daily basis or when stock position changes. The data should be provided on a floppy disk (or through a communications link if the components are not in proximity to the CINC/J-4) in a specified (for example, LOTUS 1-2-3) format.
- Establish data flows with USTRANSCOM to provide information on the numbers and types of ammunition en route to the theater, including projections of when and where they will arrive.
- Establish wartime data flows with the CINC/J-2 intelligence staff to provide data on the number of enemy TO targets remaining in different regions of the theater.
- Establish wartime data flows with the CINC/J-3 operations staff to provide data on current and planned operations, by type, intensity, and force modules, in different regions of the theater.

KNOWLEDGE BASE INITIATIVES

The data described above will only provide some of the knowledge the CINC/J-4 needs. Knowledge is also needed to convert the data to useful information and to identify solutions to supportability and sustainability problems. This knowledge includes consumption factors to assist in developing ammunition requirements for various types of

operations, commonality factors to identify other services that use a given munition or other munitions that can substitute for a preferred munition in short supply, and support factors that describe what is necessary to move, handle, and store munitions.

Whereas data are dynamic, changing rapidly in wartime, knowledge is relatively static, with few (although sometimes significant) changes occurring over time. The knowledge base can, therefore, be developed in peacetime and subjected to only periodic maintenance and update. Furthermore, the knowledge base should be essentially the same for all theaters. A concerted effort on the part of the JS should result in a knowledge base that can be distributed and used by all theaters, including the components in each theater.

The values that comprise the knowledge base should be available from various service organizations and the SMCA. Specific actions include

- Composing a list of ammunition common to more than one service and defining the interface requirements necessary for one service to use the ammunition of another service. This information should be available from the services and the SMCA.
- Composing a list of ammunition substitutes, noting the relative effectiveness of the substitute ammunition against different types of targets. This information should be available from services and the SMCA.
- Developing a set of consumption factors for different force modules and different types and intensity of operations. Such factors should be available from the services or their theater components.
- Defining the resources necessary to transport, handle, and store ammunition. The information should be available from the service components.

ANALYTIC TOOL INITIATIVES

The data and knowledge base factors only represent raw values or numbers. They must be processed by analytic tools to develop the *information* necessary to assess supportability of operations and to aggregate and display the results for the CINC and the JS. The specific tools necessary include

- A method to adjust the knowledge base consumption factors in light of recent wartime experience.

- A model to generate ammunition requirements for various types of operations.
- A model to estimate inventory based on the most recently reported asset position, expected resupplies, and expected consumption. The model should also reflect the uncertainties surrounding the expected values.
- A model to search the knowledge base and identify potential options for solving supportability problems.
- An integrated package to summarize and display the information on ammunition availabilities and requirements over time.

Current efforts parallel the development of several of these tools. The ARG model will include methods to estimate ammunition requirements and may fulfill the needs for a time-sensitive requirements generator. The C2IS under development at USCENTCOM contains various routines to aggregate data and could serve as the basis for the model to summarize and display information. Although GUARDS will contain inventory data for the theater, the data will be somewhat dated and the system will not have the ability to forecast future inventories. The inventory forecaster should be developed initially while the ARG, GUARDS, and C2IS efforts are still ongoing. When these systems reach a "final" stage, efforts should be undertaken to develop and integrate the other theater modeling requirements.

Appendix A

PLANNING FOR AMMUNITION REQUIREMENTS DURING WARTIME

At the unified command level, time-sensitive planning for logistic resources (including ammunition) is typically a reactive exercise, at the direction of CINC/J-3 crisis planners. Depending on timing and the particular candidate course of action, CINC/J-4 personnel may contribute specific analyses or remain in a monitoring role as analysis is deferred to the service component logisticians. In the case of military exercises, which generally do not emphasize logistics, very little time-sensitive logistics planning may occur.

This appendix begins with remarks on planning at USCENTCOM and USPACOM, providing the organizational context of wartime ammunition requirements analysis. This is followed by descriptions of resources (knowledge factors) that currently exist at the service components, possibly useful related modeling efforts, and a description of the forthcoming ARG, which may become a useful estimation tool at the unified level. The descriptions relating to the unified commands and their service components derive from visits to USCENTCOM and USPACOM during the summer of 1988.

CURRENT TIME-SENSITIVE PLANNING AT THE UNIFIED LEVEL

Time-sensitive planning occurs in response to specific and imminent crises with lead times measured in days and hours. Typically, little time exists for thoughtful, deliberate analyses of logistic considerations. Thus, it is important that appropriate planning tools with streamlined data linkages are established and made familiar well in advance of the need to use them.

CINC/J-4 Planning at USCENTCOM

Crisis planning at USCENTCOM is relatively flexible and adaptable, both with respect to use of the resources available for planning and to the assignment of various planning responsibilities. This flexi-

bility probably derives from USCENTCOM's experience in planning for actual combat in non-OPLAN situations.

At USCENTCOM, CINC/J-5 is in charge of deliberate planning keyed to OPLANS, but CINC/J-3 takes the lead in time-sensitive planning. The vehicle for the latter is the crisis action team (CAT), or for field operations, the joint operations center (JOC). An adjunct to the CAT/JOC is the battle management center, also a CINC/J-3 operation, which conducts planning for 72 hours and more into the future.

Service component representatives play an active part in this activity, but their role seems to depend on the particular situation. Sometimes they take the lead, but sometimes they only review and respond. Occasionally, when planning lead times are very short, CAT/JOC takes the lead, but refers to the service component operators for inputs rather than to CINC/J-4 or other CINC/J-3 units; in these cases, CINC/J-4 becomes more a monitor than an active player.

The crisis planning teams usually include at least one CINC/J-4 person, usually someone from Logistic Planning or the War Reserve Materiel Division. The different CINC/J-4 units are called upon to provide specific support as the need arises. In munitions planning, CINC/J-2 intelligence plays an important role in targeting, especially for threat-oriented items.

A CAT/JOC is convened in support of a particular crisis, accompanied by the formation of a logistics operations center (LOC). The LOC is a small, crisis-oriented unit that supports the CAT/JOC and provides a focal point for logistics and security assistance actions. In so doing, the LOC must collate relevant resource information from the various CINC/J-4 specialized resource units (ammunition; petroleum, oil, and lubricants; mobility; and so on). During mobilization, the LOC helps plan the logistic aspects of the impending operations. After the operations start, the LOC role is predominantly monitoring and troubleshooting since most of the immediate logistic decisions will have shifted to the component level.

The CINC/J-4 Programs, Analysis, and Evaluation (PA&E) branch participates heavily in crisis-action planning. It is not exclusively crisis-oriented, but it serves as a logistic analysis resource for the CAT/JOC and the LOC. The PA&E branch addresses logistic-related aspects of courses of action formulated by CINC/J-3, answering questions related to resource availability, sustainability, and adequacy of support forces. In these respects, the bulk of CINC/J-4 time-sensitive logistic analysis seems to reside in the PA&E branch.

CINC/J-4 Planning at USPACOM

During exercises or wartime, the CINC's immediate support in the execution of joint operational planning is the CAT, which resides in the joint command center. The CAT typically focuses on operations 24–48 hours into the future.

The CAT is complemented by the operations planning team (OPT), a group assembled by, and mostly from, CINC/J-3. The OPT performs planning activities for operations up to 15 days into the future.

The CAT and the OPT are supported by the logistics readiness team (LRT), the contact point for issues having to do with status of logistics resources. The LRT collates resource data from the respective CINC/J-4 resource branches and the components, prepares status briefings for the CAT, and otherwise responds to requests for information.

The CAT frequently goes to the component operators (hence indirectly to component logisticians) for answers to planning problems. Other times it may go to the DMT (deployment mobility team), whose primary mission is to constantly monitor the time phased force deployment data (TPFDD) database. In the latter case, the objective is to explore whether in-transit resources can be rerouted to the benefit of specific courses of action under consideration.

The DMT includes representatives of the Mobility Operations branch and the Logistics Planning branch, both part of the Mobility Operations and Logistics Plans Division of the CINC/J-4.

KNOWLEDGE FACTORS AT THE SERVICE COMPONENTS

Time-sensitive analysis for ammunition requirements at the service components, at least those that support USPACOM, varies from rudimentary (at the Fleet Marine Forces, Pacific [FMFPAC], for example) to model-based (at Western Command [WESTCOM], for example). The process depends heavily on use of ammunition consumption factors of varying complexity. These factors include

- Army: Standard factors;
- Air Force: Expenditure per sortie factors;
- Marines: Standard factors;
- Navy: Shipfill factors.

The FMFPAC frequently prepares logistics supportability estimates in response to United States Pacific Fleet (USPACFLT) requests for

quick assessments of the supportability of alternative courses of action, described in terms of force quantities and locations/movements, levels of threat, combat intensities, and so on. For ammunition requirements, FMFPAC uses consumption rates (published in *Marine Corps Order 8010*) that are tabulated for individuals or platforms, as appropriate. There are assault rates, sustaining rates, and a third rate that reflects availability of items in short supply. No substitution factors are used.

The U.S. Army's Central Ammunition Management Office—Pacific (CAMOPAC) has developed a PC spreadsheet munitions requirements program that can estimate ammunition requirements for a given force for a given action. The spreadsheet uses ammunition consumption rates (developed by the Concepts Analysis Agency and published by Depot Systems Command) that depend on various weapon systems, fighting postures, and battle intensities. The resulting requirements estimates are then reconciled to a database of existing inventories using a dBase III+ requirements reconciliation program. This program automatically substitutes alternative ammunition when the preferred ammunition runs short, relying on a database created from the "Conventional Ammunition Substitutability/Interchangeability List" published by the Armament, Munitions, and Chemical Command (AMCCOM).

The ammunition *consumption* factors used by the service components in this planning activity could also provide a resource for the sort of broad-brush planning models appropriate at the unified level, both (1) to improve the real-time accuracy of standard inventory reporting (from GUARDS, for example) and (2) to project the effects of future operations planning on inventories. Other useful information includes substitution factors, commonality lists, and logistic capacity factors.

In implementing this sort of application, implementers should exercise care fully understanding the premises behind the factors. The underlying assumptions, shortcomings, and incompatibilities must be recognized and understood to be tolerable for joint planning purposes.

For LOE ammunition, the factors must be relevant to specific fighting units assigned to specific missions over short periods of time. For example, factors used to plan LOE theaterwide requirements over 90-day scenarios clearly would be inappropriate because such factors "average" over levels of battle intensity that vary across fighting units and across time.

In some cases, modifying LOE consumption factors to give them more operational significance may be possible. For example, Army FM 20-32 *Mine/Countermine Operations* provides factors that translate

rounds of scatterable mines to area of coverage for particular tactical objectives.

Some effort may be necessary to make the factors mutually compatible since they may be keyed to different kinds of measures of battle intensity or operational objectives. Shipfill factors, for example, probably don't inherently depend on operations at all; the Navy, with its particular problems of resupply while under way, orients itself toward maintaining its ships' capability status rather than toward meeting particular tactical operations.

Other kinds of information, such as substitution rates, commonalities, and theater support (movement, handling, storage) factors will be more difficult to obtain, although no less important to estimating supportability of alternative courses of action. Some tabulations of ammunition substitution rates exist, but coverage is not comprehensive. Information on ammunition common across services is even more piecemeal, and it is complicated by problems of interchangeability: Two services may use the same munition, but that commonality is not operational unless the configurations of the munition-platform interfaces are compatible or modifiable. Finally, the planner cannot depend on munition backup through substitution or commonality unless capacity in terms of lift, storage, and handling are available. This information may be the most problematic of all, because it is time-variant and must be collected from a variety of sources.

RELATED MODELING EFFORTS

Although intended for other purposes, many modeling efforts incorporate techniques or factors that might be adapted in establishing a package of analytic tools for wartime munitions planning at the unified level. We note some of these in the paragraphs below.

The Army logistics center uses scenario-determined computer assisted logistics planning to assist in determining deployment requirements and developing contingency plans. It is a LOTUS spreadsheet model that applies factors and doctrine from Army FM 101-10-1 to estimate requirements for class I (subsistence), III (petroleum, oil, and lubricants), and V (ammunition) items. It also accommodates variation in resupply time and geographic characteristics.

The military capability model, developed by the Government Systems Division of GTE in Boston, was examined by the USCENTCOM PA&E branch in 1987. It was evaluated positively by the branch, whose staff felt that it was all that is needed for course-of-action analysis and that it would provide a good quantitative foundation on which to add other kinds of analysis.

Argonne Laboratories is developing a small, intratheater ground distribution analysis model. The intent is to illustrate the application of artificial intelligence techniques to unified logistics.

The USPACFLT command center is supported by a highly developed array of computerized databases and analytical models at various stages of development. None of these track logistic support resources, but logistics could conceivably be incorporated at a later date. The centerpiece is the OSGP (operations support group prototype).

The OSGP is the "fusion" system for CINCPACFLT command and control. It receives, stores, and merges information from many sources and then provides information management and display support concerning the locations, activities, and readiness indicators for ships within the area of responsibility. The OSGP supports the battle management program under development at Texas Instruments, but draws heavily upon work by the Center for Naval Analysis and by the USPACFLT operations research group. The battle management program currently consists of two artificial intelligence-based modules: CASES (capability assessment expert system) and FRESH (force requirements expert system).

Under development since late 1987, CASES generates general requirements. For example, it currently can assess antisubmarine operations in terms of strategy assessment and war plan planning/assessment, and it can generate appropriate requirements for particular types of combatant ships.

Under development since 1985, FRESH recommends specific ships for filling the requirements generated by CASES. It monitors ship readiness and capability changes, assesses the significance of operations, and identifies alternative candidates and the effects of redirecting those units.

The Navy nonnuclear ordnance requirements models for TO and LOE munitions incorporate a wealth of knowledge-type factors, some of which might be adapted to crisis-action planning. The munitions logistics capability model (CAPLOG) is under development for the Navy at Synergy, Inc. This model emulates the more complex NNOR estimating process in order to support "what if" exercises for program objection memorandum (POM) programmers and other quick-response needs, such as special congressional requests. Although CAPLOG's purpose is at variance with time-sensitive planning, it may incorporate knowledge-type factors that could be borrowed profitably.

Another model oriented to Navy requirements is the ordnance programming model developed by the Center for Naval Analysis and used for POM-86. The model performs trade-off analyses among TO

munition types at any specified level of resource constraint, calculates the sustainability associated with given ordnance inventories, and calculates the effects of changing ordnance mix.

The Marine Air-Ground Task Force lift requirements and logistics planning factor model (MAGTF I) is a TPFDD planning tool that computes lift requirements for a particular Marine air-ground task force. In so doing, the model extracts logistic planning factors from the logistics management information system for sustainment calculations. The MAGTF I will be replaced by MAGTF II, now under development by SYSCON. The MAGTF II will be a more self-contained planning model that will help Marine planners design a MAGTF for any given OPLAN. It will determine sustainment and lift requirements, then transmit the corresponding TPFDD to the joint operations planning system (JOPS) and joint deployment system.

Other applicable methods might be found in algorithms developed by Quantics, Inc., for the Office of the Secretary of Defense, dealing with the effects of target overlap (among the services) on TO munitions consumption.

AMMUNITION REQUIREMENTS GENERATOR

The ARG is a menu-driven, PC-based model developed for the Joint Chiefs of Staff (JCS) by Synergy, Inc. It is intended to generate ammunition requirements for a specified force and to compare those requirements with on-hand assets, identifying shortfalls that occur over time. The model was designed to help JCS initially evaluate the sustainability of military actions where planning is closely held at the joint level. In mid-1988, the model was operational at Synergy and at the joint data systems support center. The USCENTCOM and United States European Command have also expressed interest; they received demonstration copies in 1988. Development will be completed in mid-1989.

The ARG requires a hard disk and some basic graphic capabilities. It contains a library of fighting units designated by unit-type code, a matrix associating the major types of ammunition with those forces, and a set of algorithms for predicting the quantity of each ammunition item necessary under various conditions.

The ARG queries the user for mission types, activity rates (for example, sorties per day), and attrition rates. All inputs are specified by time period, up to 90 days. Resources can be introduced into the campaign on any day, and intensities and other factors can be varied in a limited way from day to day. Default values are automatically

available for most factors if the user does not wish to specify his own estimates. Based on those inputs (or defaults), the model will estimate the requirements per day for the different types of munitions.

The ammunition requirements and the associated stock of each munition can be plotted on the terminal screen and/or output in report fashion. Ammunition stocks must be input manually, although ARG designers plan eventually to access the GUARDS database through the worldwide military command and control system. They also plan to develop a substitutability module allowing the use of substitutes whenever preferred ammunition is in short supply.

Anyone with information on force structures and ammunition stocks can use the model. Obviously, the more the user knows about operational concepts and constraints, the better the analyses and the more useful the outputs.

The ARG does not take into account within-theater distribution of ammunition stocks, nor does it accommodate direct inputs regarding ammunition movements and resupply. This kind of information must be reflected in the way the user structures inputs and interprets outputs. Until the hookup with GUARDS, CINC users will have to depend on the components for inputs. After the connection with GUARDS, the problem of timeliness of inventory information will still exist.

Appendix B

MONITORING AMMUNITION INVENTORY STATUS

At the unified command level in a theater of operations, current procedures call for a rather opportunistic approach to wartime monitoring of ammunition inventories. This appendix describes (1) current procedures for wartime monitoring at USPACOM and USCENTCOM, (2) inventory systems at the service components that support monitoring at the unified level, and (3) GUARDS, the new monitoring system that is to become operational in 1989. The descriptions of current procedures at the unified and component levels are derived from visits to USPACOM and USCENTCOM during the summer of 1988.

CURRENT PROCEDURES BY CINC/J-4 LOGISTIC ORGANIZATIONS

Monitoring ammunition inventory status at USPACOM and USCENTCOM differs somewhat with respect to analytic content and to dependence on the service components. These differences are probably explainable as responses to differences in (1) data and analytic support from the components, (2) political/geographic characteristics of the areas of responsibility, and (3) levels of recent war-fighting activity.

Monitoring at USPACOM

At USPACOM, the Munitions branch (CINC/J-423) of the Logistics Resources Division has three people. They have very limited automated data processing support and devote significant portions of their time to transferring manually data received from the service components to an internally developed spreadsheet program. One mode monitors ammunition in peacetime; another mode, in exercises and in wartime.

During peacetime, no required data submissions to the Munitions branch from the components exist. Rather, the branch tracks assets by monitoring components' submittals to their respective reporting systems. For example, CINC/J-423 routinely receives copies of the Army Worldwide Ammunition reporting system (WARS) reports.

A USPACOM instruction (USCINPACINST C8010.6A) defines the reporting requirements in wartime. Before exercises, the Munitions branch identifies the set of munitions (the critical item list) to be reported daily. These basically are items in short supply and any other items specifically requested by JCS, USPACOM, or the component commands. A TO item is in critical shortage if stocks are less than 50 percent of the requirement. An LOE item is in "critical shortage" if its stocks are fewer than 30 DOS. For each munition, the component is ordered to provide

- Total OPLAN requirement;
- Beginning on hand;
- Numbers received;
- Numbers expended;
- Numbers lost;
- Ending on hand. The components also report ammunition storage capabilities.

Although these data are required daily in wartime, delays in relaying data from the forces to the component staffs occur. Moreover, reporting of geographic distribution or incoming shipments of ammunition is not required (although WESTCOM does submit copies of their interactions for ammunition with AMCCOM).

The Munitions branch manually transfers the data to its own reporting format, a LOTUS 1-2-3 spreadsheet that provides the basis for reporting to the CINC. The branch first calculates the number of rounds that comprise a DOS for each LOE munition type. This calculation is based on the total OPLAN requirement and knowledge of the length of the OPLAN. From the ending inventory (ending on hand), the branch then calculates the DOS figure for LOE munitions and percent of requirement for TO munitions.

The DOS calculation is simplistic and assumes that the daily requirement for a particular munition is constant throughout the exercise period, irrespective of varying operations or levels of battle intensity. The branch is attempting to introduce a new approach in which the daily requirement is different for different time frames of the exercise scenario. This approach has already been adopted by Army component logisticians.

The percent-of-requirement calculation is flawed as a sustainability measure in that it does not account for the percent of threat already killed. That is, at any point in time the ending inventory is expressed as a percent of original total requirement, not the requirement to

address the remaining threat. The branch is attempting to improve the measure using threat data supplied by CINC/J-2 Intelligence.

Monitoring at USCENTCOM

The Munitions branch at USCENTCOM does not rely on its service components to supply inventory status data directly during peacetime. The branch receives an annual "sustainability" report from the components, but otherwise creates its own inventory tracking worksheets, drawing mostly upon the following standard periodic reports of the four services' inventory status systems:

- Army: The quarterly WARS report.
- Marine Corps: From the ground munitions Marine ammunition support order for the first Marine expeditionary force.
- Air Force: For missiles, the annual TAMP tactical air missile program report. The nonnuclear conventional ammunition analysis is used for other munitions, although they don't play significantly in USCENTCOM activities.
- Navy (and Marine air): Special worksheets are periodically prepared by the Ships Parts Control Center (SPCC), which is the origin of the Navy inventory status system, the conventional ammunition integrated management system (CAIMS).

If a contingency exists, and if the CINC has not upgraded the defense conditions, the Munitions branch opportunistically updates data on 35 critical items by scrutinizing situation reports and by conferring with field logisticians when possible. During a recent firefight in the Persian Gulf, the Munitions branch was obliged to use these procedures; when the dust settled, they found they had attained 90 percent accurate ammunition accounting after one day, and complete accuracy after one week.

In such contingencies, the branch also initiates on-line queries to the respective service inventory status systems, although this approach is neither direct nor timely. For example, the CINC/J-4 has no direct access to the Navy's CAIMS, and CAIMS in any case requires several days to reflect abrupt ammunition activities.

At more serious defense condition levels, the components will be instructed to supply daily logistics status reports directly to the CINC/J-4. These are reports on items specifically requested by USCENTCOM, plus any other items identified as critical by the service components. The following data will be requested for each item:

- Total requirement (60 DOS for LOE items);
- Beginning on hand;
- Numbers received;
- Numbers expended or lost;
- Ending on hand;
- Estimated ending capability;
  - DOS for LOE ammunition
  - Percent remaining requirement for TO munitions.

As at USPACOM, this reporting does not cover incoming shipments, nor does it provide information on geographic distribution of stocks. It is more timely, however, by virtue of on-line reporting using the C2IS.

The C2IS is a SUN-based system under development for USCENTCOM. It is currently in use only in preparing tables and maps for briefings, but eventually it will be in use in monitoring resources as well. The C2IS will support distributed input of resource inventories, including the data items listed above. Each component will have its own C2IS workstation. Data will be entered into the C2IS database by each of the components and by USCENTCOM, and the standard tables and maps will instantly be updated to reflect new information. The USCENTCOM regulations instruct components to provide information on munitions status through the C2IS system every 24 hours in wartime. The system will be available to the CINC (for briefings), CINC/J-2 Intelligence, CINC/J-3 Operations, CINC/J-4 Logistics, and the components through a computer network. The software is very friendly to the user, giving [illegible] access to logistic information with a minimum of training. The computer hardware is fairly robust, cheap, and transportable, making C2IS to a forward base in USCENTCOM's area of responsibility easy if necessary.

The Munitions branch has no direct visibility over ammunition items in transit, although they can piece this information together from several sources. They have access to foreign military sales information and therefore can determine what can be borrowed back from whom. Also, any foreign military sales items that have not yet physically been delivered to the country of destination are technically U.S. property and can be diverted for use by U.S. forces.

SERVICE SYSTEMS THAT SUPPORT INVENTORY MONITORING BY THE CINC/J-4

As noted above, the CINC/J-4 logisticians rely in various ways on the inventory status reporting systems of the Air Force, Army, and Navy.

Air Force

In peacetime, the United States Pacific Air Forces (USPACAF) routinely prepare a monthly sustainability report for USPACOM. In wartime, this report would be supplemented by a daily report on the status of the most critical items.

The sustainability report covers all classes of supply and is OPLAN-specific. For ammunition, it reports the percent of OPLAN sorties that can be flown using the current aggregate inventory of some 20 ammunition types. The five or so most critical munitions are reported separately and in more detail every five or six months. The more detailed report covers the following for each munition:

- OPLAN requirement;
- Quantity on hand;
- Percent requirement (for TO munitions);
- Days of supply (for LOE munitions);
- Days of support for the OPLAN.

For its own use, USPACAF also publishes a quarterly munitions fact sheet that provides quantities on-hand and DOS (by air base) for some 60 munitions. The fact sheet shows complete rounds by (1) priority-build order, and (2) unlimited build; it also identifies the limiting components that prevent building more rounds.

These reports are assembled from data collected in what USPACAF calls the D-15/D078 system, also known as the ammunition reporting management system (ARMS). Under this system, D-15 daily transaction reports (including federal stock numbers and quantities for each munition) are prepared at all bases where there has been a change in munitions inventory. All such reports for the Pacific region are transmitted daily to USPACAF, where they are used to update the USPACAF master inventory lists and to produce the D078 report, which shows inventories for all bases in the theater. Simple error

checks are made, and the originating base is queried for clarification if necessary; the goal is to correct entries within 48 hours.

The D078 is part of the Worldwide Military Command and Control system and is therefore available to the ammunition control point at Hill Air Force Base, the Pentagon, USPACAF, and elsewhere.

The Air Force is introducing a new ammunition inventory status system, the combat ammunition system. This system will eventually support command and control within and between base level, command level, and Air Force level, with interfaces with the defense standard ammunition computer system, and with the SMCA. Supported functions will include

- Inventory tracking and control, within and between bases, theater storage, and CONUS storage;
- Planning for storage, storage realignment, and movement;
- Wartime asset reporting;
- Redistribution tasking;
- Nuclear weapons reporting;
- Both deliberate and time-sensitive requirements estimating.

Implementation is proceeding in two stages. The first stage, scheduled for late 1988, includes base-level inventory control with vertical interface to command level; in this respect it replaces the D-15/D078 system. Apparently no timetable has been set for the remaining stage.

Army

In peacetime, the Army standard Army ammunition system (SAAS) and WARS produce quarterly summary reports that are used by the USPACOM Munitions branch in tracking ammunition inventories. However, this batch/manual system is not unsuitable for the time-sensitive needs of wartime. Accordingly, CAMOPAC relies on message traffic from field units in order to determine asset levels in wartime.

The Western Command anticipates replacing SAAS by the CTASC II hardware/software system. This new system will provide increased speed, as well as more flexibility to produce customized reports and databases. The system would be suitable for wartime use.

Navy

Naval ammunition status is monitored by CAIMS. For USPACOM, status is provided through reports derived from CAIMS by

USPACFLT. The USCENTCOM is obliged to go directly to the source of CAIMS.

The CAIMS is managed at the SPCC in Mechanicsburg, Pennsylvania; it tracks all Navy munitions worldwide. On-hand assets can be extracted by location: theater, fleet, depot, and in-transit. The extracted data elements are either all-up rounds or rounds by component, with critical components identified. Shipborne munitions are categorized as ship-fill ordnance for use in the ship's own guns, cargo carried on ammunition ships, and cargo carried on combatants.

The CAIMS database also includes the annual outputs of the POM-related NNOR estimating effort. These requirements data are used in CAIMS to evaluate fair-share allocations among Navy components.

For USPACOM, USPACFLT prepares an annual report covering some 25 percent of all items tracked in CAIMS; a much shorter semi-annual report is also provided. The following are included in the reports:

- Shortfalls;
- On-hand inventories;
- In-transit;
- Unserviceable on-hand;
- Serviceable on-hand;
- Ship-fill ordnance requirements;
- Prepositioned war readiness materiel reserve (60-day requirements);
- War readiness materiel reserves (180-day requirements).

The system is fairly rigid in output, and apparently it is not amenable to inquiries aggregated at the command level. At USPACFLT, for example, it takes a senior enlisted man more than a month to prepare one of the standard reports, including abstracting and combining CAIMS data and preparing graphics. Although CAIMS is undergoing restructuring, the flexibility of output format will not likely improve.

The USCENTCOM Munitions branch builds its own up-to-date naval munitions status database by periodically requesting from the SPCC a special spreadsheet tabulating the ammunition loading on each ship in the theater, plus in-theater supply. The branch manually updates the spreadsheet as new ships are deployed to the theater and as ammunition is expended in firefighting or training. Information on the latter is obtained by querying individual ships (if possible) and by comparing other kinds of information, such as situation reports and ordinary CAIMS queries. (In the event of a more serious crisis, the

branch presumably would have more direct access to ammunition status. But at current defense condition levels, ships don't report ammunition information directly to the branch, nor apparently to the United States Central Navy.)

"Ordinary" CAIMS queries are not straightforward for USCENTCOM. The CAIMS is a limited-access system, but terminals are available at the fleet CINCs. To access CAIMS, USCENTCOM must go through the United States Atlantic Fleet, USPACFLT, and (on weekends) Navy headquarters.

Some CAIMS users have reservations about the quality of data because of input and transmission errors. Inputs originate as ammunition transaction reports that summarize daily ammunition activity at weapons stations. The preparation of those reports is generally assigned to persons of low skill who necessarily are distributed widely throughout the Navy. The transaction information must be typed onto cards, with specific data going into specific blocks; the cards are then fed to an optical scanner that has little tolerance for input variation. The data then travel to the SPCC over message traffic, inducing additional problems, including traffic snarls during times of crisis.

Marine Corps

The Marine Corps has no automated inventory status system for local use. The FMFPAC, for example, could not provide daily status for ground munitions to PACOM during war. In exercises, they usually report "no change" because they rarely play a combat role. Marine Air status is monitored by the SPCC and loaded onto CAIMS, since Marine Air is supported by the Navy. The FMFPAC has no knowledge of ammunition outside of the Pacific theater. In addition, no information of incoming ammunition exists either, except for when ammunition leaves the CONUS port.

GUARDS

The unified commands look forward to more direct and standardized monitoring of inventory status with the implementation of GUARDS. The GUARDS has actually been in place for at least a year (and in planning for at least ten years), but errors have limited its use. An effort is currently under way at the JS to correct the errors so GUARDS can have use at the unified command level. The GUARDS is intended as an automated worldwide status reporting system for selected ammunition items, particularly those of special interest to the JS, critical/short supply items necessary to support command OPLANs, and other items proposed by the services.

The JS-requested data unit[1] is the complete serviceable round, although serviceable components are acceptable until complete-round reporting by the services is feasible. For the selected items, each service reports all service-owned assets (1) in CONUS storage (or in procurement and production), and (2) in overseas storage sites, ashore, and afloat.

Services submit the data monthly (within ten days of the closing date), or more often if the JS so directs (within five days of closing date). Data can be encoded on cards or tape, preferably transmitted electronically, but the mail is acceptable. The service inputs are generated by their respective ammunition management systems: ARMS (Air Force), WARS (Army), the marine ammunition accounting and reporting system (Marine Corps), and CAIMS (Navy). Ammunition items are identified by

- Cognizant command;
- Service owner;
- Theater;
- Location type:
  - base/ammunition supply point
  - depot
  - afloat, carriers
  - afloat, ammo ship
  - afloat, other
  - en route ship
  - in transit within area
  - in transit within CONUS
  - in transit, other
- Geographic location code;
- Department of Defense identification code;
- Federal stock number.

Two additional kinds of information are submitted for each item:

- Planned consumption during the first 180 days of combat:
  - D to D+30
  - D+31 to D+60
  - D+61 to D+90
  - D+91 to D+180

[1]According to JCS, *General Unified Ammunition Reporting System*.

- Asset accounting for the reporting period:
  - On hand at report cutoff date
  - Actual expenditures (combat, training, and test)
  - Prepositioned war reserve materiel requirement
  - Receipts from all sources
  - Transfers-out within same service
  - Transfers-out to other services.

The GUARDS is just currently becoming operational for the CINCs. The USCENTCOM Munitions branch does not currently use GUARDS because so many errors exist. The USPACOM Munitions branch received its GUARDS password in mid-1988, but as of August 1988 had not used the system.

The GUARDS apparently will not be vested heavily with software that would assist in analyzing its data. A 1985 contractor (CEXEC) proposal lists several objectives not supported collectively by the JS ammo management triad (GUARDS, JOPS, and the joint deployment system), including

- Assessing ammo supportability for OPLAN or other courses of action;
- Projecting trends in weapon density to actual and planned ammo stockage requirements;
- Assessing impact of foreign military sales/host nation support agreements on U.S. ammo stockage;
- Locating and diverting assets in transit.

These objectives presumably will require manual input of GUARDS data into other models. If so, GUARDS will be replicating a shortcoming often attributed to service inventory systems such as CAIMS.

BIBLIOGRAPHY

Army Regulation 700-22, *Worldwide Ammunition Reporting System,* RCS CSGLD-1322, October 1983.

Berg, Robert M., *The CNA Ordnance Programming Model and Methodology,* Professional Paper 424, Center for Naval Analysis, October 1984.

Bolmarcich, Joseph J., *Estimating Target Overlap for Munitions Sustainability Planning,* Quantics Inc., August 1987.

Crawford, Gordon, *The Air Force's Munitions Requirements Process (The Nonnuclear Consumables Annual Analysis),* The RAND Corporation, N-2821-P&L, March 1989.

Davall, B. M., *Artillery Firing Rates: A Special Report for the U.S. Army Human Engineering Laboratory,* Armament Systems Inc., September 1981.

Department of the Army, Headquarters, *Staff Officers' Field Manual: Organizational, Technical, and Logistic Data,* Field Manual 101-10-1, July 1976.

Department of the Army, Headquarters, *Ammunition Service in the Theater of Operations,* Field Manual 9-6, January 1984.

Department of the Army, Headquarters, *Mine/Countermine Operations,* Field Manual 20-32, December 1985.

Girardini, Kenneth, *The Army's Conventional Munitions Acquisition Process,* The RAND Corporation, N-2864-P&L, July 1989.

Hamlin, F. J. and D. G. Harmon, *Survey of the U.S. Army Ammunition Logistics System Concept,* The BDM Corporation, W-86-0101-TR, February 1986.

Joint Chiefs of Staff, *The Unified Action Armed Forces,* JCS Publication 2, December 1986.

Joint Chiefs of Staff, *General Unified Ammunition Reporting System,* JCS Publication 6, Volume 2, Part 13, Chapter 3, January 1982.

Joint Chiefs of Staff, *Memorandum for Attendees, Joint Planning and Execution Systems Conference; Subject: Ammunition Requirements Generator,* July 1988.

Landrum, Lt. Col. B. F., *An Analysis of the Army Conventional Ammunition Rate Studies,* U.S. Army War College, Carlisle Barracks, Penn., April 1982.

Linville, Lt. Col. Ray P., "Analytical Methods and Techniques for Logistics Planning," *Logistics Spectrum,* Spring 1988, pp. 7–11.

Moore, S. C., J. P. Stucker, and J. F. Schank, *Wartime Roles and Capabilities for the Unified Logistic Staffs*, The RAND Corporation, R-3716-JS, 1990.

Starkand, C. L., and J. McNeer, *Continuation and Expansion of the Force Module Logistics Sustainability Model for the JDSSC: Task 3, Subtask 1, Final Draft Functional Description*, Synergy, Inc., February 1988.

Sumner, Gerald, *Conventional Munitions Requirements Estimation in the Navy*, The RAND Corporation, N-2853-P&L, April 1989.

U.S. Air Force, *Combat Ammunition System: System Operational Concept*, November 1987.

U.S. Army Studies and Analysis Directorate, *Ammunition Planning Factor System: Study Draft Report*, January 1987.

U.S. Army Training and Doctrine Command, *U.S. Army Operational Concept for Ammunition Support on the Airland Battlefield*, TRADOC PAM 525-49, January 1986.

U.S. Army Western Command, *Method of Computing and Reporting Munition Sustainment*, Briefing.

U.S. Marine Corps, *Combat Service Support*, FMFM 4, March 1987.

U.S. Marine Corps Order 8010.

White, G. A., and S. D. O'Connell, *Munitions Analysis Process Logistics Information Requirements*, Systems Research and Applications Corporation, April 1986.